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Full Length Research Paper

Growth and survival of budded Kinnow plants as influenced by different types of black polybags and soil media

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The experiment was carried out to standardize the black polybags with different soil media for production of budded Kinnow plants with treatments comprising four different sizes of black polybags and different soil media containing soil, sand, vermicompost and farm yard manure (FYM) in different proportions. The interaction effect of different potting material and propagation media showed that potting material viz. black polybags of size 22x10x8 cm with holes filled with propagation media soil: sand: vermicompost in the ratio of 1:1:1 reported maximum diameter of scion (0.89 cm), diameter of stock (2.76 cm), scion stock ratio (0.32), length of shoot (20.00 cm), number of shoot (11.81), number of leaves per scion (12.50) and height of plant (44.96 cm); whereas, soil temperature, electrical conductivity and soil texture were also observed highest. The cost of raising 10000 kinnow buddlings in black polybags of size 22x10x8 cm with holes filled with propagation media soil: sand: vermicompost in ratio of 1: 1: 1 was estimated as Rs 54321.00.

Key words: Kinnow, black polybags, soil media, growth and economics.

INTRODUCTION

Kinnow mandarin (*Citrus reticulata* Blanco), member of family Rutaceae, is one of the popular fruit among various citrus species. Among various citrus species, it has greater heat tolerance than other citrus species; a character inherited from its parent cultivar *king tangor* which allows it to survive in hot summers with maximum temperatures around 48°C. The fruit become popular among citrus growers by virtue of its excellent desert quality, characteristic aroma, pleasing appearance in addition to the cultivar's precocious bearing habit and adaptability to adverse weather conditions.

In India, citrus is grown as field nursery. In field nurseries, the eradication of soil borne pathogens like Phytophthora once introduced becomes very difficult. To avoid this problem, the concept of containerised nursery system was adopted. Natural development of the root system remains more or less intact in polybags which ensures better growth, helps the trees resist strong winds and gives better drought protection in the initial years. The increased root length of container grown seedlings allows better performance and survival under adverse conditions than bare root (Amidon et al., 1982). Interest in

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producing quality planting material by application of improved and modern nursery technique has increased in recent years (Gera and Ginwal, 2002). Therefore, it has become imperative to standardize the black polybags with different soil media for raising budded Kinnow plants.

MATERIALS AND METHODS

The study was carried out in the experimental farm of the Division of Fruit Science, Faculty of Agriculture, SKUAST-J Udheywalla Jammu, during the year December 2011/2012 to February 2012/2013. Udheywalla is situated in the sub-tropical zone at latitude of 32.40°N and longitude of 74.58°E. The altitude is 300 m above mean sea level. Annual precipitation is about 1200 mm. The winter month experiences mild to severe cold and temperature ranges from 6.5 to 21.70°C. December is the coldest month with minimum temperature and evaporation rate goes as low as 4.0°C; however the maximum, minimum temperature and evaporation rate rises from March onwards. In order to study the growth characteristics of the budded kinnow plants, the rootstock seedlings were procured. The rootstock seedlings used for the budding of kinnow plants was one and half year old having uniform vigour and of pencil thickness at the time of budding. Seedling rootstock was budded during spring season. Four different black polybags viz. C_1 black polybags of size 25×13×10 cm with holes, C_2 black polybags of size 22×10×8 cm with holes, C_3 black polybags of size 17×7×6 cm with holes and C_4 Nursery bed (Size = 1×1 m) filled with six different propagation medias viz. M_1 Soil: FYM 2:1, M_2 Soil: Sand: FYM 1:1:1, M_3 Soil: Sand: FYM 2:1:1, M_4 Soil: Vermicompost 2:1, M_5 Soil: Sand: Vermicompost 1:1:1and M_6 Soil: Sand: Vermicompost 2:1:1 were used forming 24 numbers of treatments. The treatments were arranged in a Factorial Randomized Block Design with three replications and the data generated during the course of study was subjected to statistical analysis as prescribed by Panse and Sukhatme (2000).

By considering the growth of budded kinnow plants, vegetative parameters like diameter of the scion and stock of five budded kinnow plants was measured using a digital vernier caliper at 30, 60, 90, 120, 150 and 180 days after planting and was expressed in centimeters. The length from the collar region to the tip of the shoot apex was measured for five randomly selected plants in each treatment and expressed in centimetres, number of shoots per plant of five budded kinnow plants was recorded at 30, 60, 90, 120, 150 and 180 days for six months after planting. All the shoots on the bud-scions were counted and average number of shoots per plant was calculated, number of leaves of five budded kinnow plants was recorded at 30, 60, 90, 120, 150 and 180 days for six months after planting. On each plant, all the leaves irrespective of their sizes were counted and average numbers of leaves per plants were calculated. The height of the budded kinnow plants was recorded at 30, 60, 90, 120, 150 and 180 days for six months after planting. The linear growth (height) was measured from ground level to the tip of the main axis with the help of scale and expressed as an average plant height in centimeter (cm).

RESULTS AND DISCUSSION

The maximum scion diameter (0.89 cm) was recorded at 180 days after transplanting in black polythene bag of size 22x10x8 cm with holes filled with soil: sand: vermicompost (1:1:1) in Table 1. These results are in line with the findings of Bahuguna and Pyarelal (1990) in *Acacia nilotica*, who reported the addition of FYM and vermicompost, recorded maximum growth of plants in the nursery.

The maximum diameter of stock (2.76 cm) in Table 2 was recorded at 180 days after transplanting in black polybags of size 22 x 10 x 8 cm with holes filled with soil: sand: vermicompost (1:1:1). It follows in Table 3 then, that the maximum scion stock ratio (0.32) was observed in treatment C_2M_5 (black polybags of size 22 x 10 x 8 cm with holes) filled with soil: sand: vermicompost (1:1:1). These results are in consonance with Ouma (2006), who reported that increase in container volume increases plant growth parameters such as height of plants, stem diameter in rough lemon seedlings.

Maximum shoot length (20.0 cm) was recorded at 180 days after transplanting in treatment C_2M_5 (black polybags of size 22 x 10 x 8 cm with holes filled with soil: sand: vermicompost 1:1:1) presented in Table 4. This increase in the shoot growth might be due to the conducive effect of this medium mixture on porosity, soil aeration and supplying sufficient nutrients particularly nitrogen, and micro nutrients required for good root and shoot growth (Chopde et al., 1999). Maximum number of shoots (11.81 cm) were recorded at 180 days after transplanting in treatment C_2M_5 (black polybags of size 22x10x8 cm with holes filled with soil: sand: vermicompost 1:1:1) presented in Table 5. This may be due to the larger container volume, which led to increased development of primary shoots and their number and total length of all shoots increased (Alvarez and Caula, 1993) resulting in increased plant height and canopy size.

Maximum number of leaves per shoot (12.50) were recorded at 180 days after transplanting in treatment C_2M_5 (black polybags of size 22x10x8 cm with holes filled with soil: sand: vermicompost 1:1:1) presented in Table 6. The increased leaves per shoot might be the result of availability of nutrients from added organic matter. These results are supported by Alvarez and Caula (1993) who found that the increase in number of leaves was due to the content of higher volume of rooting media which increased development of primary shoots and their number.

Maximum height of the plant (44.96 cm) at 180 days after transplanting in treatment C_2M_5 (black polybags of size 22x10x8 cm with holes filled with soil: sand: vermicompost 1:1:1) is presented in Table 7. The results are in consonance with Chatterjee and Choudhuri (2007) who reported that vermicompost provides close contact between seed and media, increases steady moisture supply facilitates root respiration and encourages overall root growth. They observed that at large volumes of container, there was increased development of primary shoots and their number and total length of all shoots increased which caused increased heights of plants (Alvarez and Caula, 1993).

Perusal to the data presented in Table 8 showed that maximum soil temperature was observed (36°C) in the black polybags with holes and treatments comprising

Table 1. Interaction effect of black polybags and potting mixtures on diameter of scion (cm) at different intervals for six months on budded kinnow plants.

Treatment	30 days	60 days	90 days	120 days	150 days	180 days
Black polybags x Potting mixtures						
C_1M_1	0.23	0.27	0.34	0.41	0.50	0.59
C_1M_2	0.35	0.37	0.45	0.52	0.60	0.69
C_1M_3	0.34	0.36	0.44	0.51	0.59	0.68
C_1M_4	0.29	0.31	0.39	0.46	0.54	0.63
C_1M_5	0.43	0.47	0.53	0.66	0.75	0.84
C_1M_6	0.42	0.45	0.52	0.65	0.74	0.83
C_2M_1	0.25	0.29	0.37	0.43	0.52	0.61
C_2M_2	0.39	0.41	0.49	0.58	0.67	0.76
C_2M_3	0.38	0.40	0.48	0.56	0.65	0.74
C_2M_4	0.31	0.33	0.41	0.48	0.56	0.65
C_2M_5	0.47	0.52	0.61	0.71	0.80	0.89
C_2M_6	0.46	0.51	0.57	0.70	0.79	0.88
C_3M_1	0.24	0.28	0.36	0.42	0.51	0.60
C_3M_2	0.37	0.39	0.47	0.54	0.63	0.72
C_3M_3	0.36	0.38	0.46	0.53	0.62	0.71
C_3M_4	0.30	0.32	0.40	0.47	0.55	0.64
C_3M_5	0.45	0.50	0.56	0.69	0.78	0.87
C_3M_6	0.44	0.49	0.55	0.68	0.77	0.86
C_4M_1	0.22	0.26	0.33	0.40	0.49	0.58
C_4M_2	0.33	0.35	0.43	0.50	0.58	0.67
C_4M3	0.32	0.34	0.42	0.49	0.57	0.66
C_4M_4	0.28	0.30	0.38	0.44	0.52	0.62
C_4M_5	0.41	0.43	0.51	0.63	0.72	0.81
C_4M_6	0.40	0.42	0.50	0.60	0.69	0.78
C.D	N.S	0.03	0.02	0.02	0.02	0.02

C_1M_2, C_2M_2, C_2M_5, C_3M_5 respectively, after transplanting of budded kinnow plants to the open field. The Table 8 also indicates the maximum electrical conductivity (29 µm) in the black polybags with holes in the treatments C_1M_5 and C_2M_6 respectively. It follows then that maximum sand percentage (84%), silt percentage (20.14 %) and clay percentage (7.51 %) was recorded after transplanting of budded kinnow plants to the open field with the treatment comprising C_2M_5 (black polybags of size 22x10x8 cm with holes filled with soil: sand: vermicompost 1:1:1) presented in Table 8.

The economics for producing 10000 budded kinnow plants in black polybags of size 22 x 10 x8 cm with holes filled with soil: sand: vermicompost (1:1:1) revealed that maximum gross income (Rs. 198000), net return (Rs. 143679) and C: B ratio (1:2.74) was observed in black polybags of size 22x10x8 cm with holes filled with propagation media soil: sand: vermicompost (1:1:1), Table 9.

These results are in conformity with findings of Ravikumar (2007) and Pramod (2007).

Conclusion

It can be concluded that the black polybags of size 22 x 10 x 8 cm with holes filled with soil: sand: vermicompost (1:1:1) was found to be best for nursery raising of budded kinnow plants and the relative economics for producing 10000 budded kinnow plants in black polybags is calculated to be Rs. 54321 for which cost of planting single kinnow plant in black polybags cost to Rs. 5.24.

Table 2. Interaction effect of black polybags and potting mixtures on diameter of stock (cm) at different intervals for six months on budded kinnow plants.

Treatment	30 days	60 days	90 days	120 days	150 days	180 days
Black polybags x Potting mixtures						
C_1M_1	1.10	1.25	1.43	1.63	1.81	2.05
C_1M_2	1.65	1.80	1.98	2.18	2.36	2.46
C_1M_3	1.55	1.70	1.88	2.08	2.26	2.36
C_1M_4	1.32	1.47	1.65	1.85	2.03	2.13
C_1M_5	1.91	2.06	2.24	2.44	2.62	2.72
C_1M_6	1.89	2.04	2.22	2.42	2.60	2.70
C_2M_1	1.23	1.38	1.56	1.76	1.94	2.30
C_2M_2	1.81	1.96	2.14	2.34	2.52	2.62
C_2M_3	1.77	1.92	2.10	2.30	2.48	2.58
C_2M_4	1.40	1.55	1.73	1.93	2.11	2.21
C_2M_5	1.95	2.10	2.28	2.49	2.66	2.76
C_2M_6	1.94	2.09	2.27	2.47	2.65	2.75
C_3M_1	1.20	1.35	1.53	1.73	1.92	2.08
C_3M_2	1.64	1.79	1.97	2.17	2.35	2.45
C_3M_3	1.68	1.83	2.01	2.21	2.39	2.49
C_3M_4	1.35	1.50	1.68	1.88	2.06	2.16
C_3M_5	1.93	2.08	2.26	2.46	2.64	2.74
C_3M_6	1.92	2.07	2.25	2.45	2.63	2.73
C_4M_1	1.00	1.15	1.33	1.53	1.71	2.04
C_4M_2	1.53	1.68	1.86	2.06	2.24	2.34
C_4M3	1.46	1.61	1.79	1.99	2.17	2.27
C_4M_4	1.29	1.44	1.62	1.82	2.00	2.10
C_4M_5	1.88	2.03	2.21	2.41	2.59	2.69
C_4M_6	1.84	1.99	2.17	2.37	2.55	2.65
C.D	0.07	0.03	0.07	0.03	0.02	0.07

Table 3. Interaction effect of black polybags and potting mixtures on scion stock ratio at different intervals for six months on budded kinnow plants.

Treatment	30 days	60 days	90 days	120 days	150 days	180 days
Black polybags x Potting mixtures						
C_1M_1	0.21	0.21	0.23	0.25	0.27	0.29
C_1M_2	0.21	0.20	0.23	0.23	0.25	0.28
C_1M_3	0.22	0.21	0.23	0.24	0.26	0.29
C_1M_4	0.22	0.21	0.23	0.24	0.26	0.30
C_1M_5	0.22	0.23	0.24	0.27	0.28	0.31
C_1M_6	0.22	0.22	0.23	0.27	0.28	0.31
C_2M_1	0.20	0.20	0.24	0.24	0.26	0.27
C_2M_2	0.21	0.21	0.23	0.25	0.27	0.29
C_2M_3	0.21	0.21	0.23	0.24	0.26	0.28
C_2M_4	0.22	0.21	0.23	0.25	0.26	0.30
C_2M_5	0.24	0.24	0.27	0.29	0.30	0.32
C_2M_6	0.23	0.24	0.25	0.28	0.30	0.32
C_3M_1	0.19	0.20	0.23	0.24	0.26	0.29
C_3M_2	0.23	0.21	0.24	0.25	0.27	0.30
C_3M_3	0.21	0.21	0.23	0.24	0.26	0.29
C_3M_4	0.22	0.21	0.24	0.25	0.26	0.30
C3M5	0.23	0.24	0.25	0.28	0.29	0.32

Table 3. Contd.

C_3M_6	0.22	0.24	0.24	0.28	0.29	0.31
C_4M_1	0.21	0.23	0.24	0.26	0.28	0.29
C_4M_2	0.21	0.21	0.23	0.24	0.25	0.28
C_4M3	0.22	0.21	0.23	0.24	0.26	0.29
C_4M_4	0.21	0.21	0.23	0.24	0.26	0.29
C_4M_5	0.22	0.21	0.23	0.26	0.28	0.30
C_4M_6	0.21	0.21	0.23	0.25	0.27	0.29
C.D	N.S	0.02	0.02	0.02	0.01	0.02

Table 4. Interaction effect of black polybags and potting mixtures on length of shoot (cm) at different intervals for six months on budded kinnow plants.

Treatment	30 days	60 days	90 days	120 days	150 days	180 days
Black polybags x Potting mixtures						
C_1M_1	1.08	1.75	6.55	9.20	13.00	17.86
C_1M_2	1.88	2.45	7.25	9.85	13.68	18.45
C_1M_3	1.80	2.40	7.20	9.75	13.61	18.39
C_1M_4	1.40	2.04	6.80	9.54	13.21	18.05
C_1M_5	2.38	2.94	7.74	10.42	14.24	19.10
C_1M_6	2.30	2.86	7.66	10.37	14.12	19.00
C_2M_1	1.26	1.86	6.73	9.36	13.10	17.92
C_2M_2	2.10	2.70	7.50	10.16	14.00	18.80
C_2M_3	2.05	2.65	7.45	10.08	13.92	18.75
C_2M_4	1.59	2.18	7.00	9.60	13.39	18.23
C_2M_5	2.60	3.20	8.00	11.00	15.10	20.00
C_2M_6	2.55	3.15	7.98	10.64	14.42	19.60
C_3M_1	1.18	1.80	6.60	9.30	13.05	17.90
C_3M_2	2.00	2.55	7.38	10.00	13.92	18.72
C_3M_3	1.94	2.57	7.35	9.90	13.84	18.50
C_3M_4	1.50	2.15	6.95	9.58	13.38	18.10
C_3M_5	2.48	3.08	7.95	10.60	14.40	19.30
C_3M_6	2.42	3.02	7.80	10.50	14.26	19.20
C_4M_1	1.00	1.70	6.50	9.00	12.75	17.40
C_4M_2	1.72	2.30	7.10	9.74	13.50	18.35
C_4M3	1.65	2.20	7.05	9.66	13.46	18.28
C_4M_4	1.35	2.00	6.75	9.42	13.20	18.00
C_4M_5	2.25	2.82	7.60	10.28	14.09	18.98
C_4M_6	2.17	2.77	7.55	10.27	14.03	18.86
C.D	0.02	0.04	0.03	0.04	0.05	0.06

Table 5. Interaction effect of black polybags and potting mixtures on number of shoot at different intervals for six months on budded kinnow plants.

Treatment	30 days	60 days	90 days	120 days	150 days	180 days
Black polybags x Potting mixtures						
C_1M_1	1.03	1.33	1.58	1.85	2.11	2.45
C_1M_2	1.40	2.49	4.20	4.65	4.78	5.12
C_1M_3	1.37	2.48	3.67	3.99	4.50	4.84
C_1M_4	1.20	1.67	2.54	2.71	2.89	3.23
C_1M_5	1.72	4.40	6.13	6.86	7.38	7.72

Table 5. Contd.

C_1M_6	1.62	4.22	6.08	6.54	6.95	7.29
C_2M_1	1.09	1.48	2.28	2.31	2.87	3.21
C_2M_2	1.48	3.30	5.55	5.83	5.69	6.03
C_2M_3	1.47	3.16	5.03	5.28	5.58	5.92
C_2M_4	1.25	2.07	2.67	2.79	3.32	3.68
C_2M_5	2.47	5.60	8.92	10.03	11.47	11.81
C_2M_6	2.00	4.93	8.59	9.21	9.50	9.84
C_3M_1	1.07	1.42	1.72	2.29	2.33	2.67
C_3M_2	1.44	3.02	4.86	4.91	5.19	5.53
C_3M_3	1.42	2.58	4.76	4.75	4.97	5.31
C_3M_4	1.23	1.93	2.58	2.75	3.00	3.34
C_3M_5	1.88	4.80	7.13	7.72	8.61	8.95
C_3M_6	1.80	4.55	6.82	7.26	7.67	8.01
C_4M_1	1.00	1.15	1.44	1.49	1.53	1.87
C_4M_2	1.33	2.33	3.44	3.75	3.83	4.17
C_4M3	1.28	2.20	3.10	3.50	3.55	3.89
C_4M_4	1.13	1.55	2.29	2.64	2.83	3.17
C_4M_5	1.53	3.63	6.04	6.04	6.38	6.72
C_4M_6	1.50	3.43	5.70	5.87	6.19	6.53
C.D	N.S	0.10	0.03	0.03	0.03	0.04

Table 6. Interaction effect of black polybags, potting mixtures on number of leaves per shoot at different intervals for six months on budded kinnow plants.

Treatment	30 days	60 days	90 days	120 days	150 days	180 days
Black polybags x Potting mixtures						
C_1M_1	2.60	3.45	3.72	5.00	7.75	10.75
C_1M_2	2.79	3.64	4.14	5.90	8.73	11.46
C_1M_3	2.78	3.63	4.08	5.85	8.50	11.38
C_1M_4	2.70	3.55	3.83	5.59	8.02	11.00
C_1M_5	2.90	3.75	4.62	6.30	9.24	12.00
C_1M_6	2.88	3.73	4.50	6.26	9.18	11.96
C_2M_1	2.66	3.50	3.76	5.50	7.86	10.90
C_2M_2	2.83	3.68	4.38	6.10	9.00	11.76
C_2M_3	2.82	3.67	4.30	6.05	8.96	11.68
C_2M_4	2.72	3.58	3.94	5.64	8.16	11.15
C_2M_5	3.00	3.85	4.80	6.72	9.50	12.50
C_2M_6	2.98	3.83	4.74	6.66	9.43	12.20
C_3M_1	2.63	3.48	3.74	5.45	7.80	10.86
C_3M_2	2.81	3.66	4.25	6.00	8.90	11.60
C_3M_3	2.80	3.65	4.18	5.96	8.84	11.58
C_3M_4	2.71	3.57	3.88	5.60	8.09	11.04
C_3M_5	2.95	3.80	4.70	6.60	9.38	12.14
C_3M_6	2.93	3.78	4.66	6.44	9.32	12.05
C_4M_1	2.55	3.40	3.70	4.98	7.60	10.56
C_4M_2	2.77	3.62	4.05	5.72	8.38	11.30
C_4M3	2.74	3.60	4.00	5.68	8.22	11.22
C_4M_4	2.67	3.53	3.80	5.55	7.92	10.97
C_4M_5	2.85	3.71	4.42	6.20	9.10	11.92
C_4M_6	2.84	3.70	4.35	6.18	9.04	11.80
C.D	0.02	0.02	0.04	0.03	0.03	0.03

Table 7. Interaction effect of black polybags, potting mixtures on height of plant (cm) at different intervals for six months on budded kinnow plants.

Treatment	30 days	60 days	90 days	120 days	150 days	180 days
Black polybags x Potting mixtures						
C_1M_1	16.00	17.72	20.27	23.57	26.57	27.82
C_1M_2	18.30	20.85	23.95	27.82	31.28	34.68
C_1M_3	17.98	20.60	23.85	27.50	31.18	34.63
C_1M_4	17.05	19.05	21.85	26.07	29.12	32.04
C_1M_5	20.60	23.62	27.53	30.86	35.10	39.19
C_1M_6	20.51	23.59	27.42	30.72	34.98	39.07
C_2M_1	16.40	18.26	20.99	24.01	27.22	30.32
C_2M_2	19.30	22.16	25.50	29.03	33.05	36.44
C_2M_3	18.65	21.96	25.45	28.90	32.86	36.39
C_2M_4	17.45	19.63	22.63	27.00	30.44	33.66
C_2M_5	22.65	25.80	29.80	34.86	39.96	44.96
C_2M_6	22.56	25.76	29.75	34.52	38.94	43.23
C_3M_1	16.11	17.91	20.51	23.91	26.66	29.43
C_3M_2	18.55	21.35	24.49	28.72	32.64	36.18
C_3M_3	18.54	21.06	24.20	28.40	32.35	36.06
C_3M_4	17.08	19.23	22.18	26.69	30.08	33.36
C_3M_5	21.36	24.22	27.88	31.38	35.56	39.96
C_3M_6	20.85	23.79	27.57	31.26	35.50	39.48
C_4M_1	15.97	17.70	20.20	21.72	24.82	29.06
C_4M_2	17.91	20.38	23.61	27.33	30.94	34.40
C_4M3	17.71	20.36	23.58	27.06	30.50	33.89
C_4M_4	16.70	18.74	21.49	24.65	27.85	30.91
C_4M_5	19.83	22.60	26.20	29.87	33.96	37.81
C_4M_6	19.35	22.53	26.08	29.16	33.16	37.05
C.D	0.03	0.04	0.03	0.03	0.03	0.03

Table 8. Interaction effect of black polybags, potting mixtures on soil physical characteristics on budded kinnow plants after six months of planting.

Treatment	Soil temperature (°C)	Electrical conductivity (µm)	Texture		
			Sand (%)	Silt (%)	Clay (%)
Black polybags					
C_1	34.67	26.28	79.50	14.03	6.03
C_2	35.06	26.83	80.26	14.64	6.25
C_3	34.72	25.66	80.03	14.35	6.17
C_4	32.71	25.99	79.10	13.78	5.87
C.D	0.42	0.12	0.17	0.13	0.05
Potting mixtures					
M_1	33.75	24.85	75.06	10.79	4.83
M_2	35.17	26.63	82.40	17.70	6.58
M_3	34.63	26.47	79.79	12.42	6.10
M_4	33.75	23.45	76.47	11.41	5.41
M_5	34.83	28.03	83.66	19.26	7.25
M_6	33.60	27.71	80.98	13.62	6.30
C.D	0.52	0.14	0.20	0.15	0.06
Black polybag x Potting mixtures					
C_1M_1	34.00	25.10	75.00	10.71	4.69

Table 8. Contd.

C_1M_2	36.00	26.70	82.11	17.74	6.54
C_1M_3	35.00	26.40	79.89	12.08	6.09
C_1M_4	34.00	23.60	76.33	11.17	5.37
C_1M_5	35.00	28.00	83.46	18.98	7.24
C_1M_6	34.00	27.85	80.22	13.48	6.27
C_2M_1	35.00	25.00	75.68	10.96	5.06
C_2M_2	36.00	27.40	82.89	17.88	6.76
C_2M_3	35.00	27.20	80.09	13.12	6.20
C_2M_4	34.33	24.00	76.99	11.70	5.60
C_2M_5	36.00	29.00	84.00	20.14	7.51
C_2M_6	34.00	28.40	81.92	14.03	6.35
C_3M_1	34.00	24.50	75.34	10.95	5.07
C_3M_2	35.67	26.12	82.58	17.78	6.63
C_3M_3	35.00	26.05	79.96	12.67	6.09
C_3M_4	34.00	23.00	76.67	11.58	5.53
C_3M_5	36.00	27.30	83.98	19.44	7.35
C_3M_6	33.67	27.00	81.66	13.68	6.34
C_4M_1	32.00	24.80	74.22	10.55	4.52
C_4M_2	33.00	26.30	82.00	17.40	6.39
C_4M3	33.50	26.22	79.20	11.80	6.02
C_4M_4	32.67	23.20	75.88	11.17	5.13
C_4M_5	32.33	27.80	83.20	18.47	6.92
C_4M_6	32.73	27.60	80.12	13.29	6.25
C.D	1.04	0.28	0.41	0.31	0.12

Table 9. Economics for producing 10000 budded kinnow plants in polybag of size 22 x 10 x 8 cm with holes filled with media Soil: Sand: vermicompost (1:1:1) ratio.

S. No.	Items of cost	Amount (Rs.)
	Variable cost	
1	Human labour (3 labour for 5 days @ Rs 160/day)	2400
2	Cost of polybags (10000) at 1300 per 1000 piece	13000
3	Cost of Vermicompost	1200
4	Plant protection chemicals	2000
5	Irrigation charges	1000
6	Interest on working capital at 10%	1960
	Total variable cost (V.C)	21560
	Fixed cost	
7	Permanent hired human labour	30000
8	Depreciation on assets	700
9	Estimation rental value of land	500
10	Land revenue	25
11	Interest on fixed capital at 6%	1536
	Total Fixed cost (F.C)	32761
	Total cost	54321
	Cost of planting single kinnow plant in polybag	54321/10000=5.24
	Return structure	
12	No. of seedlings	10000
13	Price per seedling	22
14	No of seedlings alive at 10% mortality	9000

Table 9. Contd.

Total value of output (seedlings)	198000
Net return (profit)	
Total cost of cultivation	54321
Gross income	198000
Net return	143679
C:B ratio	1: 2.74

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Effect of growth conditions on reducing properties of maize (*Zea mays* L.) root exudates

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In the present study, impacts of nitrate/ammonium ratios, aluminum and phosphate stress on the reduction properties of five-leaf maize root exudates were investigated using hydroponic culture method. Appropriate nitrate/ammonium ratio (3:1) prompted maize roots to secrete more organic reducing substances which led to more release of Mn^{2+} from MnO_2. Under stress of low phosphorous and high aluminum, maize roots release more reducing substances, and more Mn^{2+} was released into the solution after the root exudates were reacted with MnO_2. The amount of reducing substances secreted by maize roots gradually increased with the culture time with the initial Al concentration of 20 μmol L^{-1}. The similar trend was observed for the dissolved Mn^{2+} after the reaction of root exudates with MnO_2. Therefore, root exudates can alleviate Al toxicity and activate phosphate in acid soils under low P and high Al, but they may increase the toxicity of Mn^{2+} to plants.

Key words: Active reducing substances, MnO_2, reduction reaction, release of Mn^{2+}, maize.

INTRODUCTION

Soil acidification is the main problem of integrative agriculture in China. There are a large area of acidic Ultisols and Alfisols in the regions south of the Yangtze River, which results in the decrease of production and quality of crops (Hseung and Li, 1990). The toxicity of Al(III) and Mn(II) limit plant growth in acid soils. Manganese exists as Mn oxides in solid phase in soils, but they could be reduced to Mn^{2+} by plant root exudates, when local redox potential is lower. As a result, if the concentration of Mn^{2+} reaches up to a certain degree, plants will be susceptible to be poisoned (Godo and Reisenauer, 1980; Uren 1981; Posta et al., 1994). Adams (1984) suggested that when the reducible Mn extracted by NH_2OH-HCl in soils was above 50 - 100 mg kg^{-1}, Mn toxicity to plants occurred. Lei et al. (2007) reported that even 0.1 mM in culture solution significantly reduced the shoot height and biomass accumulation of two contrasting populations of *Populus cathayana*.

Plant roots can not only take in water and nutrient from growth matrix, but also release proton, inorganic ions and organic substances named as root exudates, which are considered to be important channel of interaction between root-soil interface and play the role of a "language" in the rhizosphere dialogue (Iijima et al., 2003). This is because plant root exudates are wetting agents in root-soil interface and microbial energy

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materials, and meanwhile can come into effect in resistance to various environmental stresses through adjusting the process of roots/soil interface. Root exudates are effective in the dissolution of hydrous MnO_2 (Godo and Reisenauer, 1980). Stone (1987) found that the reductive dissolution of manganese (III/IV) oxides by 10 substituted phenols followed the order: p-methylphenol > p-ethylphenol > m-methylphenol > p-chlorophenol > phenol > m-chlorophenol > p-hydroxybenzoate > o-hydroxybenzoate > 4'-hydroxyacetophenone > p-nitrophenol. Lehmann and Cheng (1988) found that reductive reactions of the manganese (III/IV) oxides in soils by phenolic acids followed the order: p-hydroxybenzoate < vanillic acid < syringic acid < cumaric acid < ferulic acid < sinapic acid. Under adverse conditions, plant can change the types and amount of root exudates so as to adapt to environmental stresses (Neumann and Römheld, 2007). For example, under aluminum stress, the roots of some plants can secret organic acids, phosphoric acids, and phenolic compounds to alleviate aluminum toxicity by complexation, precipitation, block and barrier effect (de Andrade et al., 2011; Ma, 2005; Kidd et al., 2001; Kochian et al., 2004; Ofei-Manu et al., 2001; Ryan et al., 2009; Taylor and Bloom, 1998). Under P deficiency stress, some plants secrete organic acids to facilitate the activation of insoluble P in soils. Roots of maize, radish and rape can release a large amount of organic acids such as citrate acid, malic acid, tartaric acid, succinic acid (Zhang et al., 1997; Carvalhais et al., 2011). The amount of phenolics exuded from bean roots under phosphate-deficient condition was five times higher than that under normal condition (Juszczuk et al., 2004).

Appropriate nitrate/ammonium ratio plays an important part in plant growth (Kronzucker et al., 1999; Drüge, 2000). The growth index and contents of nitrogen and phosphorus in onion seedlings without inoculation of arbuscular mycorrhizal fungi are highest when the ratio of nitrate/ammonium is 3:1 (Guo et al., 2006). At the genetic level, the nitrate/ammonium ratios, as a signal, determine immune function of *EDS1* through regulating the generation of NO (Wang et al., 2013). Under different nitrate/ammonium ratios, the higher proportion of NH_4^+-N led to the higher plant nitrogen content (Ali et al., 2000), and the stronger ability to adapt to adversity (Flores et al., 2001). The nitrate/ammonium ratios in nutrient solutions affected the release of proton/hydroxyl and organic acids from plant roots, and consequently influenced the availability of metals and obligatory nutrients to plants (Wan et al., 2012).

The roles of plant root exudates in alleviation of aluminum toxicity and activation of phosphorus in acid soils have been investigated extensively. However, few studies involved in the reduction properties of root exudates. We hypothesized that plant roots may release the exudates which contain reducing substances and can reduce soil MnO_2 to Mn^{2+}. Hence, the objectives of the present study were to investigate the effect of growth conditions on the release of reducing substances from maize roots and study the ability of root exudates to reduce MnO_2.

MATERIALS AND METHODS

Maize (*Zea mays* L. cv. Jiangyu 403) was obtained from Academy of Agricultural Sciences of Jiangsu Province, China. MnO_2 was produced by Shanghai Xingta Chemical Plant in China.

Hydroponic culture method

Maize seeds were sterilized by 30% hydrogen peroxide for 15 min, then washed by tap water, and rinsed by distilled water at last. After the washing process, the seeds were placed into plastic boxes, and incubated in a 25°C thermostatic incubator and moisturized for sprouting. When the buds grew to 1 cm, the seeds with uniform shoot were selected and put onto the 2 mm plastic net which contacted with the surface of nutrient solution. The endosperms were removed at three-leaf stage of maize. Hoagland's nutrient solution (pH 5.5) with nitrate/ammonium ratio of 3:1 were employed, in which the concentrations of NO_3^-, NH_4^+, P ($H_2PO_4^-$), K, Ca and Mg were 12, 4, 1, 6, 4, 2 M, and the concentrations of B, Mn, Cu, Zn, Mo and Fe (Fe-EDTA) were 46.26, 9.15, 0.32, 0.77, 0.02, 20.0 µM, respectively. The nutrient solutions were changed every day. The maize plants at five-leaf stage were used to investigate effects of the growth conditions on the amount of reducing substances in maize root exudates. In order to avoid the disturbance of Mn and Fe-EDTA, Mn and Fe-EDTA were not added in the nutrient solution in the following experiments.

Experiment 1

Effect of nitrate/ammonium ratios on the amount of reducing substances in maize root exudates. Nutrient solutions with different nitrate/ammonium ratios (15:1, 5:1 and 3:1) were prepared, in which total nitrogen concentration is 16 mmol L^{-1}, the concentrations of other nutrients are the same with Hoagland's nutrient solution except NO_3^- and NH_4^+. The pH of nutrient solutions was adjusted to 5.5 with HCl or NaOH. The uniform seedlings were selected and put into 500 ml tall beaker contained nutrient solutions. The beaker was packed with aluminum foil outside to make the roots away from light, and then placed them into a illumination growth chamber at 27°C/20°C day/night, 14 h daylength (8:00-20:00)/10 h nightlength (22:00-8:00), 150 Wm^{-2} light intensity and 65% relative humidity. Due to water loss induced by plant transpiration, the volume of nutrient solutions was adjusted at the end of cultivation with distilled water. After 24 h cultivation, maize roots were harvested, and the nutrient solutions were collected for determination of root exudates. The roots harvested were dried at 105°C first for stop the activity of enzymes and then at 80°C till constant weight. Each treatment was repeated five times, and solutions without corn plants were used as controls.

Experiment 2

Effect of aluminum stress on the amount of reducing substances in maize root exudates. Hoagland's nutrient solutions with different Al(III) concentrations (0, 10, 20, 30 and 50 µmol L^{-1}, respectively) were prepared using $AlCl_3 \cdot 6H_2O$. The pH of solutions was adjusted to 4.5, and the root secretions were collected with the same procedures used in Experiment 1. When the kinetics of reducing materials under aluminum stresses were studied, a Hoagland's nutrient solution with initial Al concentration of 20 μM was used. The maize root exudates were sampled at 2, 5, 8, 11 and 24 h during cultivation.

Experiment 3

Effect of phosphorous stress on the amount of reducing substances in maize root exudates. Hoagland's nutrient solutions with different phosphate concentrations (0, 0.01, 0.1, 0.5 and 1 M) were prepared. The pH of solutions was adjusted to 5.5, and the root secretions were collected with the same procedures used in Experiment 1.

Determination of active reducing substances in root exudates

Root exudates of 10 ml were put in a 50 ml conical flask, and distilled water was added to make total solution volume 25 ml approximately. 2 ml 1:1 H_2SO_4 was added immediately, and then the solutions were titrated with 0.004 M $KMnO_4$ at room temperature until solution became slightly red, and did not fade for 30 s (Yu, 1985). A blank titration was also conducted.

Determination of total reducing substances

10 to 20 ml root exudates were put in a 100 ml conical flask with glass plug, and 5 ml of 0.007 M $K_2Cr_2O_7$, 5 ml of 1:1 H_2SO_4 and some distilled water were added to make the total solution volume 40 to 50 ml. Conical flasks with plugs covered were heated in water bath and maintained at 90 to 95°C for 20 min. After cooling, 2 drops of ferrous-phenanthroline indicator were added, and subsequently 0.01 M ferrous ammonium sulfate solution was applied to titrate residual $K_2Cr_2O_7$ (Yu, 1985). A blank titration was conducted.

Reaction between root exudates and MnO_2

20 mg MnO_2 was weighed and put into a 100 ml plastic bottle, and 30 ml root exudates and 10 ml sodium acetate solution (buffered pH at 4.5) were added. N_2 gas was blew into the mixture for 1 min, and then plugs were covered immediately. The bottles sealed up were shaken in a 28°C air bath for 24 h. The supernatant liquid was taken out, and concentration of soluble Mn^{2+} was determined by atomic absorption spectroscopy (Nov AA 350).

Data analyses

The amount of reducing substances in control was deducted from that of each treatment. The data were divided by the root dry weight, and the results were expressed as the amount of reducing substances per unit dry roots. In order to compare active and total reducing substances suitably, all data of titration were multiplied by the number of transferred electrons in corresponding reactions. SPSS 16.0 software was employed for data analyses.

RESULTS AND DISCUSSION

The amount of reducing substances in maize root exudates at different nitrate/ammonium ratios

The amount of reducing substances in maize root exudates increased continuously with the decrease of nitrate/ammonium ratio. When nitrate/ammonium ratio dropped from 15:1 to 5:1, the amount of active reducing substances increased more obviously (Table 1). Total reducing substances changed similarly with decrease of nitrate/ammonium ratio and increased significantly (P < 0.05), when nitrate/ ammonium ratio declined from 15:1 to 5:1, and then decreased slightly with further decline of nitrate/ammonium ratio to 3:1 (Table 1). Appropriate nitrate/ammonium ratio promotes plant growth (Kronzucker et al., 1999; Drüge, 2000), and thus leads to more reducing substances secreted from plant roots.

Redox reaction occurred between maize root exudates and MnO_2, which led to reduction of Mn(IV) to Mn^{2+}. More active reducing substances secreted at low nitrate/ammonium ratio resulted in the greater amount of Mn(IV) to be reduced and dissolved into solution (Table 1). Maize root exudates contained organic acids such as aspartic acid, glutamic acid, malic acid, citric acid, and aconitic acid and other organic acids (Carvalhais et al., 2011). These organic acids have certain reduction ability and can react with MnO_2 which led to reductive dissolution of Mn(IV). Uptake of NH_4^+ by plants induced more amino acids secreted from plant roots compared uptake of NO_3^- (Mahmood et al., 2002), which may be responsible for the increase in reducing substances of maize root exudates with the decline of nitrate/ammonium ratio.

Effect of aluminum stress on the amount of reducing substances in maize root exudates

Both active and total reducing substances increased gradually with the increase of initial aluminum concentration in the nutrient solution (Figure 1), which suggested that aluminum stress induced more reducing substances secreted from maize roots. The amount of Mn^{2+} in solutions after the reaction of root exudates with MnO_2 increased with the increasing initial concentration of aluminum in nutrient solutions and reached the maximum value at the initial aluminum concentration of 20 μM and then decreased with the further increase in the concentration of aluminum. When the maize roots were under aluminum stress, they secreted low molecular weight organic acids such as citric acid, malic acid and phenolic compounds to alleviate aluminum toxicity (Kidd et al., 2001). These organic compounds could form complexes with aluminum to reduce aluminum toxicity; on the other hand, they proceeded redox reactions with MnO_2, leading to the reductive dissolution of Mn(IV) and may increase the toxicity of Mn^{2+} to plants.

Figure 2 shows the dynamics of reducing substances in maize root exudates at the initial Al concentration of 20 μM . During the 24 h cultivation, both active and total reducing substances secreted by maize roots increased gradually with the increase of culture time, and Mn^{2+}

Table 1. Effect of different nitrate/ammonium ratios on the reduction features of maize root exudates.

Nitrate/ammonium ratio	Active reducing substances	Total reducing substances	Mn^{2+}
	---------------------- [mmol /kg dry root)]----------------------		
15:1	357.9±133.3[a]	725.7±189.1[b]	4.3±1.3[a]
5:1	703.4±49.7[a]	2035.0±242.5[a]	5.3±0.7[a]
3:1	804.3±232.2[a]	1872.4±254.1[a]	6.7±0.9[a]

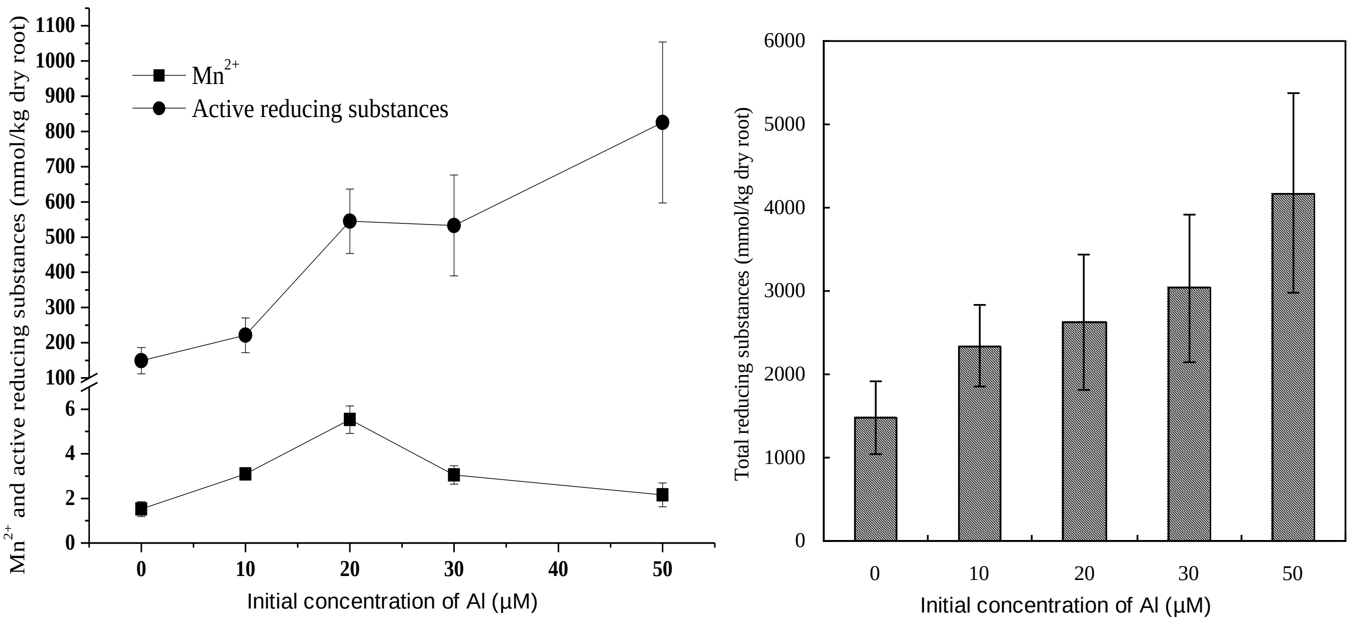

Figure 1. Effect of aluminum stresses on the reduction features of maize root exudates.

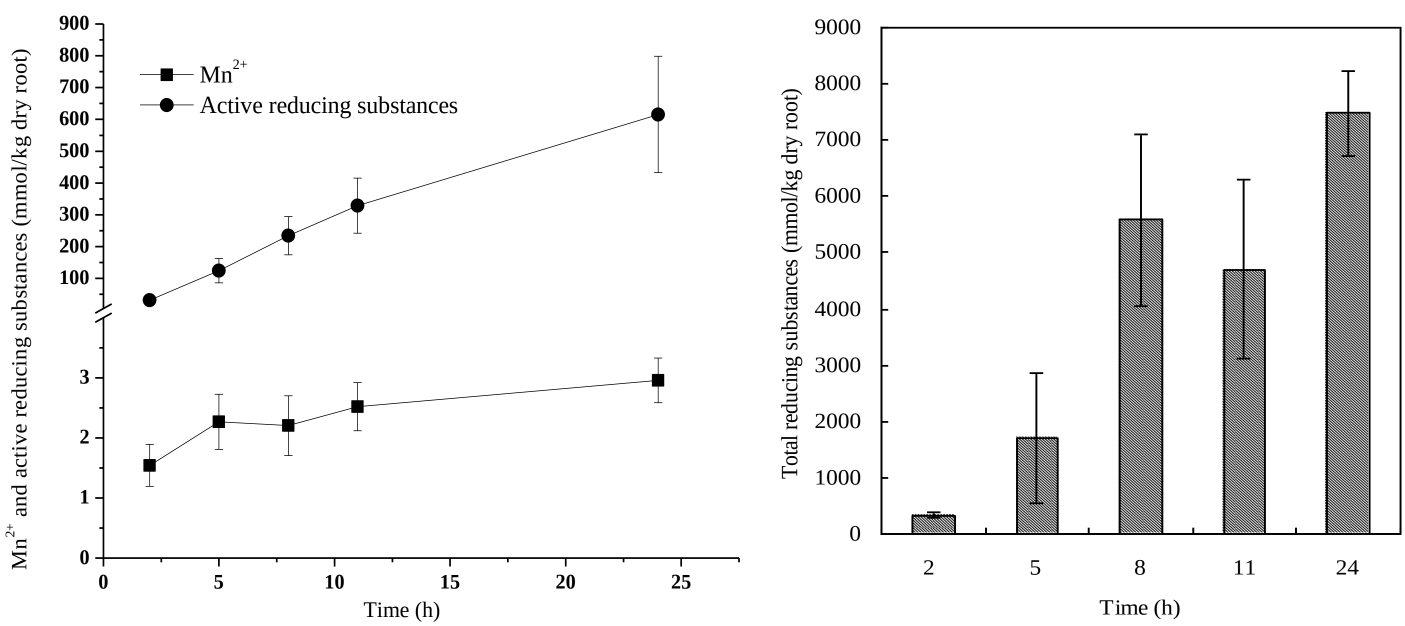

Figure 2. Kinetics of reducing features of root exudates under 20 μmAl^{3+} stress.

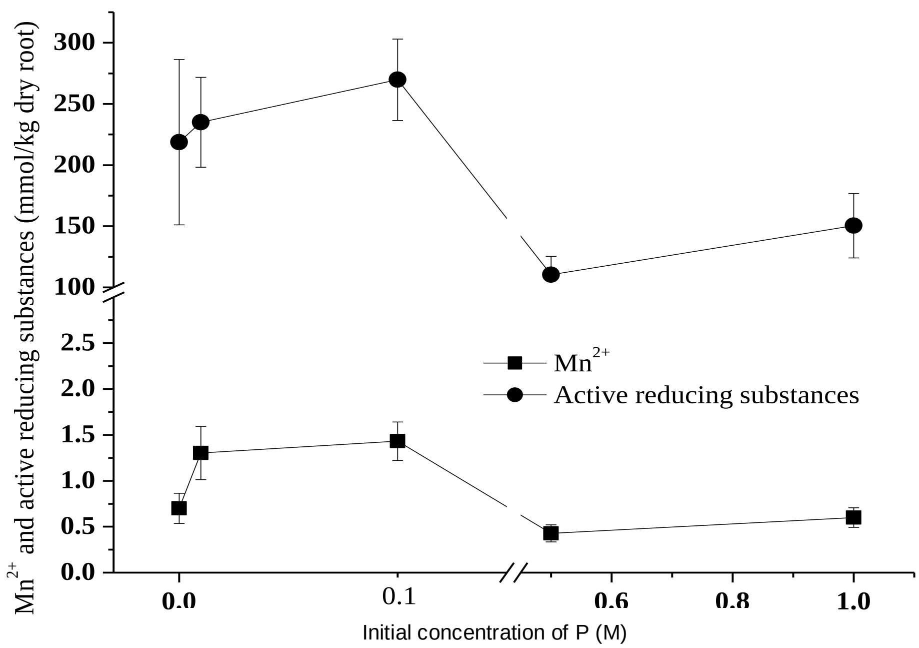

Figure 3. Effect of phosphate stresses on the reduction features of maize root exudates.

released due to the redox reaction between root exudates and MnO_2 augmented accordingly. From Figure 2, it is obvious that the amount of active and total reducing substances secreted by maize roots in the first 8 h increased linearly, and the fitting linear equation is y = 33.748x – 38.571 (R^2 = 0.9974) for active reducing substances, and y = 875.91x – 1840.2 (R^2 = 0.9304) for total reducing substances, respectively. This 8 h duration was in the daytime, so maize could use the optimal light and temperature to proceed active photosynthesis and metabolism, which led to more root exudates secreted. When night came, the rate of metabolism became slowly. As a result, the rate of root exudates secreted decreased with culture time accordingly.

Effect of phosphate stress on the amount of reducing substances in maize root exudates

The maize roots secreted more active reducing substances under low phosphorus stress compared with higher concentration of phosphorus (Figure 3). When the concentration of phosphate was 0.1 M, more active reducing substances secreted from maize roots led to more reductive dissolution of Mn(VI) and more Mn^{2+} released into the solution after the redox reaction of root exudates with MnO_2. The changing tendency of the amount of active reducing substances secreted by maize roots with the increasing concentration of phosphate was the same with the total reducing substances (data not showed). The bioavailability of phosphorus is low in acid soils due to fixation of phosphorus by iron and aluminum oxides. When plants suffer from phosphorus stress, their roots can secrete organic compounds such as organic acids to activate the phosphorus in the soils (Carvalhais et al., 2011; Zhang et al., 1997). However, the increase of active reducing substances in root exudates increased the reduction and dissolution of Mn(IV), and thus increased the risk of Mn^{2+} toxicity to plants.

Conclusions

Aluminum toxicity and low bioavailability of phosphorus are widely considered to be the important growth-limiting factors for plants in acid soils (pH < 5.5). The organic acids and phenolic compounds are secreted by corn roots to alleviate aluminum toxicity and activate phosphorus under the stresses of high concentration of Al and low concentration of P. However, these organic substances possessed reducing properties, and could proceed redox reactions with MnO_2, resulting in more reduction and dissolution of Mn(IV) and increase of phytotoxicity of Mn^{2+}. Appropriate nitrate/ammonium ratio prompted maize growth, and hence led to more organic reducing substances secreted from its roots and greater amount of Mn^{2+} released from MnO_2 due to reductive dissolution of Mn(IV).

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Reproductive performance of crossbred dairy cattle in selected urban and peri-urban farms of mid rift valley, Ethiopia

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This study was conducted to evaluate reproductive performance of crossbred cows and to identify potential constraints of dairying under small and medium scale farmers' management in urban and peri-urban dairying of mid rift valley, Ethiopia. The data was collected through questionnaire from 120 small and medium dairy farm owners. The overall estimated mean age at first service and age at first calving was 20.6±02 and 30.6±0.19 months, respectively, and differed (P<0.01) considerably among production systems and herd size groups. The overall estimated mean lactation length, days open and calving interval were 311.3±2.8 and 128.2±2.4 days and 14.07±0.09 months, respectively, and differed significantly (P<0.01) between production systems and herd size groups. According to the respondents, feed shortage and limitation of space were reported as major constraints of dairy production in urban area, whereas feed cost, shortage of feed and Artificial Insemination (AI) service were major constraints of the peri-urban production system. Therefore, from the current study it was concluded that the reproductive performances of animals on both production systems and farm scale were below their expected genetic potential. Hence, large variation between production systems and farm scale groups showed the opportunities for further improvement with strategic supplementation of energy and protein rich feeds.

Key words: Production system, reproduction, crossbred cows, challenges, Shashamane, Ethiopia.

INTRODUCTION

The economy of Ethiopia is largely based on agriculture, which accounts for about 46% of gross domestic product (GDP) and 85% of total employment (World Fact Book, 2013). The major agricultural activities are crop farming and livestock production in which the dominant production system is small scale crop-livestock system (MoARD, 2007). Livestock products supply animal protein that improves the nutritional status of human beings. Ethiopia is believed to have the largest livestock population in Africa, of which the contribution of cattle is significant. According to the Central Statistical Agency (CSA, 2012), Ethiopia has about 52.13 million heads of

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cattle. This estimate excludes cattle population in Afar and Somali Regional States. Dairy production is an important component of livestock production in Ethiopia. It is practiced in almost all parts of the country across all agro-ecological zones. In Ethiopia, market-oriented urban and peri-urban milk productions are emerging as main suppliers of milk and dairy products to the cities. They possess both indigenous and crossbred dairy animals ranging from 50% to high grade Holstein Friesian breeds in small, medium and large sized farms. They depend on purchased roughage and concentrate feeds with limited grazing for milk production. In Ethiopia the reproductive performance of dairy cattle is low due to low quality and quantity of feed resources, poor nutritional management, genotype and health care, marketing system, extension services and training (Kelay, 2002; Azage et al., 2013).

Shashamane is one of the biggest and highly populated cities in the southern part of the country with high potential for milk production. Urban and peri-urban dairy production is an important component of livestock production system in and around the city. There are numerous dairy farms in the area which ranges from small to medium-scale and most of them keep crossbred dairy cows. The previous study, conducted by Sintayehu et al. (2008), focused mainly on marketing and processing of dairy products in Shashamane Dilla area. Whereas the reproduction performance of crossbred dairy cows, whose contribution has a great role to urban and peri-urban milk production has not been studied. Hence, current and up-to-date baseline information is lacking in urban and peri-urban areas on reproductive performance of crossbred dairy cows under prevailing situations. This study was, therefore, aimed to look into the reproductive performance of crossbred cattle and production constraints in mid-rift valley, Ethiopia.

MATERIALS AND METHODS

Study area

The study was conducted in and around Shashamane city which is one of the high potential areas for milk production in Ethiopia. It is located at 7011'09" to 7013'19" N and 38035'02" to 38037'05" E at about 250 km south of the capital Addis Ababa. It is situated at about 1900 to 2400 m above sea level. The study area is characterized by bimodal rain fall pattern receiving average annual rainfall ranging from 800 to 1300 mm, with short rain season from March to April, and the main rain season from June to October, followed by long dry season. The mean minimum and maximum annual temperature is 12 and 27°C, respectively (Wazardo, 2011). Intensive urban and peri-urban dairy production is mainly practiced by crossbred dairy owners in the area.

Sampling and data collection procedures

A preliminary visit was conducted in the study area to get general picture of the study sites and to identify the target farms. In order to identify milk producing households (HH's), an initial list of dairy farms in the city of Shashamane and three related peri-urban areas were considered from West Arsi Zone. There were 497 small and 96 medium size farms of which 69% were urban and 31% were peri-urban. Based on the relative distance from the center of the city and number of crossbred cattle owned, two major dairy production systems and two herd size groups were identified in the area. Thus, dairy farms in Shashamane and three associated peri-urban areas were purposively identified based on their potential to produce milk and supply to Shashamane city. Urban production system is located within the city while the peri-urban one is located at about 5 to 20 km from the city. Then, dairy farm households were categorized into two groups based on the number of dairy cows owned as suggested by Ike (2002) as small (<4 cows) and medium (4 to 10 cows). A total of 120 households were selected for this study. Then, about 12% of the small and 62.5% of medium size farms that is, 60 households from each farm scale were purposely selected for the study. Information was gathered by interviewing the household heads and farm managers using a semi-structured questionnaire. The study was conducted between September and December, 2012.

Statistical analysis

Data collected were analyzed using Statistical Analysis System software (SAS, 2004). Descriptive statistics were employed to describe qualitative variables. General Linear Model (GLM) procedure of SAS (2004) was used for analyzing data collected on reproductive performances. Mean comparison was done using the Least Significant Difference (LSD) for parameters with significant difference. Differences were considered statistically significant at 5% level of significant. Indices were developed to provide the total ranking of the prevailing constraints of milk production and handling limitations in the study area. Data generated on reproductive performances were analyzed using the following model

$$Y_{ij} = \mu + A_i + B_j + e_{ij}$$

Where, Y_{ij} = response variables (nutrients intake, productive and reproductive performance of dairy cows), μ = overall mean, A_i = fixed effect of i^{th} production sub-system (i= 1, 2), B_j = fixed effect of j^{th} herd size (j= 1, 2), e_{ij} = residual effect

RESULTS AND DISCUSSION

Household characteristics

The proportion of female headed dairy farms in the present report was higher than 12% reported by Sintayehu et al. (2008); for Shashamane Dilla area, which might be due to increased involvement of women in dairy sector due to better market access to sell milk. On the other hand, the involvement of female headed households in dairy production was higher in urban production than peri-urban production system (Table 1) which might be related to better market access in urban areas. With regard to educational level of dairy producers, higher proportion of dairy farm owners completed primary and above primary school level of education. On the other hand, higher proportion of urban producers were completed above secondary school level of education (certificate and above), than peri-urban system. The difference could be attributed to better access

Table 1. Gender and educational level of dairy producers in Shashamane milkshed.

Variables	Sex of household head (%)		Educational level of household head (%)					
	Male	Female	Illiterate	Reading only	Primary school	Junior school	Secondary school	Above secondary
PS								
Urban (n= 60)	76.7	23.3	13.3	16.7	26.7	6.7	23.3	13.3
Peri-urban (n=60)	83.3	16.7	15	15	35	16.7	11.7	6.6
Karara Filicha (n=20)	90	10	20	15	35	25	5	-
Kuyera (n=20)	85	15	10	15	40	20	15	10
Arsi Negele (n=20)	75	25	15	20	30	10	15	10
Herd size								
Small (n=60)	75	25	26.7	16.7	26.7	10	11.7	8.3
Medium (n=60)	83.3	16.7	1.7	15	35	13.3	23.3	11.7
Overall (n=120)	80	20	14.2	15.8	30.8	11.7	17.5	10

n= number of household head, PS= production syste

to school in urban system compared to peri-urban system.

Occupational status of households

The involvement of farmers in dairy production in the current report was higher than 13.7% reported for Sebeta Awsa area (Dereje, 2012) (Table 2). Higher involvement of farmers in dairy production in the current report might be related to attractive market access in the area. Generally, the result of this study indicates that dairying is the major occupation for the majority of the respondent household head dairy producers in area.

Purpose of milk production, farm activity and income source

The major purpose of milk production in the area was income generation and family consumption (Table 3). On the other hand 53.3 and 40% of interviewed dairy holding households in urban and peri-urban areas generate their major income from sale of dairy products, respectively. Among the respondent households in different farm scales, 43.3% of small and 50% of medium scale farms also generate their major income from sale of dairy products in the study area. High proportions of peri-urban dairy farming households (36.7%) were generating their major income from crop production, whereas, only 5% of urban households generates their major income from crop production. Among dairy producers in peri-urban areas, 55% of farmers in Kerara Filicha generate their main income from crop production. About 41.7% of urban and 23.3% of peri urban dairy producers generate their main income from nonfarm activities (trading, employment in government organizations and pension).

Herd size and composition of dairy cattle

This study showed that the average herd size per house hold was similar in urban and peri-urban areas (Table 4). Higher herd size of 3.2 and 11.3 cattle was reported for small and medium scale farms, respectively, in Dire Dawa city (Emebet and Zeleke, 2007). In all the systems, farmers possessed dairy cows followed by heifers as their future herd replacement animals. It was reported that the proportion of milking cows accounted for 66 and 68% of total cows in urban and peri-urban farms, respectively, indicating that slightly higher proportion of productive cows were held in both cases. The distributions of cows on their productive state showed that about 37.4% were pregnant and milked, 28.6% milked and non pregnant, 31.7% were dry pregnant and 2.3% were dry and non pregnant among the total number of cows in urban farms, whereas, the values in peri-urban farms were 34.3% pregnant and milked, 33.7% milked and non pregnant, 26.4% dry pregnant and 5.6% were dry and non pregnant. In both cases, higher numbers of cows were pregnant and lactating. Higher proportions of pregnant milking cows in urban and peri-urban farms might be related to long lactation length in the area. The proportion of dry cows in this study was higher than the ideal recommended value of 17% set by Radostits et al. (1994). Keeping these herds require extra expenses for their feeding and other management. Compared to the current study, high percent (14%) non pregnant dry cows were reported by Mohamed et al. (2003) in Harar milkshed.

Reproductive performance of dairy cows

The mean reported age of heifers at first service and calving were short for urban farms compared to the peri-

Table 2. Major occupational status of selected household heads in Shashamane milkshed.

Variables	Household head occupation (%)					
	Housewife	Trader	Dairy farming only	Farmer	Civil servant	Pensioner
Production system						
Urban (n=60)	16.7	23.3	28	5.3	15	11.7
Peri-urban (n=60)	5	15	25	43.3	6.7	5
Karara Filicha (n=20)	-	5	25	60	-	10
Kuyera (n=20)	5	25	20	40	10	-
Arsi Negele (n=20)	10	15	30	30	10	5
Herd size						
Small (n=60)	15	26.7	10	23.3	15	10
Medium (n=60)	6.6	11.7	48.3	20	6.7	6.7
Overall (n=120)	10.8	19.2	29.2	21.7	10.8	8.3

Table 3. Landholding, purpose of milk production, farm activity and income sources of households in the study area.

Variables	Land holding (ha)	Purpose of milk production (%)			Farm activity (%)		Major income source (%)		
		Income generation and family consumption	Family consumption only	Income generation only	Livestock production only	Crop and livestock production	Sale of dairy products	Crop production	Non-farm activities
Production system									
Urban (n=60)	0.13±0.03	93.3	3.3	3.5	93.3	6.7	53.3	5	41.7
Peri-urban (n=60)	0.71±0.13	93.3	1.7	5	56.7	43.3	40	36.7	23.3
Kerara Filicha(n=20)	1.06±0.31	95	-	5	60	40	30	55	15
Kuyera(n=20)	0.88±0.2	90	5	5	50	50	55	30	15
Arsi Negele (n=20)	0.2±0.04	95	-	5	60	40	35	25	40
Herd size									
Small (n=60)	-	95	5	-	66.7	33.3	43.3	26.7	30
Medium(n=60)	-	91.7	-	8.3	83.3	16.7	50	15	35
Overall(n=120)	0.42±0.07	93.3	2.5	4.2	75	25	46.7	20.8	32.5

n= number of farms, ha = hectare.

urban farms (Table 5). The result for age at first service was in agreement with the mean value of 20.1 months reported for crossbred dairy heifers in Addis Ababa milk shed (Yoseph, 1999). However, the mean age at firstcalving in the current report was shorter than 32.2 months reported for crossbred dairy heifers under urban and peri-urban production systems of north western Ethiopian highlands (Yitaye, 2008). The mean reported days open was significantly different (P<0.05) between production systems and among the herd sizes groups (P<0.01). The mean days open was short for urban farms (122.9±3.5 days) compared to peri-urban farms (133.5±3.1days). The result was not in agreement with the mean value of 87 days reported for days open for crossbred dairy cows in and around Gondar city (Nibret, 2012). The mean reported days open was higher in dairy cows with small herd sizes (140.1±3.6 days) compared to dairy cows in medium sizes (116.3±2.3 days). Long days open estimated for small herd size groups in this study was not in agreement with the one reported by Emebet (2006) in which days open was shorter for dairy cows in small herd size than medium herd size groups. The difference in days open between different production systems and herd size groups might be related to difference in management such as nutrition, health and heat detection by farmers which affect interval from calving to first estrus and service and hence days open. The mean reported value of calving to conception interval in this study was higher than the optimum level of 80 -85 days.

Table 4. Herd size and composition of crossbred cattle in Shashamane milk shed by production system and herd size.

Variables	Production sub-systems					
	Urban			Peri-urban		
	Small (n=30)	Medium (n=30)	Mean ±SE	Small (n=30)	Medium (n=30)	Mean ±SE
Herd size (mean ±SE)	2.6±0.2	7.5±0.29	5.08±0.35	2.3±0.16	7.06±0.24	4.7±0.34
Herd composition (mean ±SE)						
Cows	1.53±0.09	4.1±0.23	2.8±0.21	1.64±0.1	4.3±0.19	2.9±0.2
Milking cows	1.06±0.08	2.6±0.13	1.85±0.12	1.3±0.08	2.9±0.17	2.1±0.14
Pregnant milking (%)	30.4	40	37.4	22	39	34.3
Non pregnant milking (%)	39.2	24.8	28.6	56	25	33.7
Dry cows	0.47±0.09	1.5±0.14	0.95±0.1	0.34±0.08	1.5±0.21	0.9±0.13
Pregnant dry (%)	26	33.6	31.7	16	30.5	26.4
Non pregnant dry (%)	4.4	2.3	2.3	6	5.5	5.6
Heifers (1-3 years age)	0.43±0.09	1.5±0.17	0.9±0.12	0.3±0.08	0.96±0.14	0.6±0.09
Pregnant (%)	38.5	45.7	44	33.3	41.4	39.5
Non pregnant (%)	61.5	54.3	56	66.7	58.6	60.5
Heifer calves (1-11 months)	0.44±0.09	1.2±0.15	0.8±0.09	0.26±0.09	0.8±0.13	0.5±0.08
Male calves (1-18 months)	0.2±0.07	0.4±0.09	0.3±0.06	0.1±0.07	0.8±0.13	0.46±0.09
Breeding bulls	0.0	0.3±0.08	0.15±0.01	0.0	0.2±0.03	0.1±0.02
Dominant cattle breeds (% Farms)						
Friesian crosses	100	96.7	98.3	93.3	90	91.7
Friesian crosses and local zebu	0.0	3.3	1.7	6.7	10	8.3
Presence of other species of animals (sheep, poultry and donkey) (% Farm)	16.7	100	58.3	26.7	100	63.3

n= number of respondents, SE= standard error.

Table 5. Least square means (LSM ±SE) reproductive performance of crossbred cows.

Variables	Reproductive indices				
	AFS (months)	AFC (months)	LL (days)	DO (days)	CI (months)
Overall	20.6±0.2	30.6±0.19	311.3±2.8	128.2±2.4	14.07±0.09
Production system	**	**	**	*	**
Urban	20.03±0.23^b	29.9±0.21^b	318.8±4.13^a	122.9±3.5^b	13.6±0.11^b
Peri-urban	21.2±0.32^a	31.2±0.31^a	303.7±3.8^b	133.5±3.1^a	14.5±0.13^a
Herd size	**	**	**	**	**
Small	21.5±0.3^a	31.4±0.28^a	297.8±3.01^b	140.1±3.6^a	14.5±0.14^a
Medium	19.7±0.23^b	29.7±0.2^b	324.7±4.3^a	116.3±2.3^b	13.6±0.1^b

$^{a-b}$ means with different superscript in the same column for the same trait do significantly differ, SE= standard error; AFS= age at first service; AFC= age at first calving; LL= lactation length; DO= days open; CI= calving interval; *= P<0.05; **= P<0.01.

The mean reported calving interval of dairy cows in urban farms was significantly (P<0.01) shorter than peri-urban farms. The value in this study was comparable with 13.93 months reported for crossbred cattle in Gondar city (Nuraddis et al., 2012) and shorter than 1.31 and 1.62 years reported for crossbred cattle in urban and peri-urbanfarms, respectively, in Northern Ethiopia (Gebrekidan et al., 2012). Estimated value of calving interval for dairy cows in medium scale farms was significantly (P< 0.01) shorter than dairy cows in small scale farms. The result of the current study was longer than the mean calving interval of 13.9 and 12.8 months reported for crossbred cattle in small and medium farms, respectively in Gondar city (Nuraddis et al., 2012). The calving interval in this study particularly for dairy cows in peri-urban areas and small scale farms was longer than the recommended interval of 12 to 13 months as indicated by Kiwuwa et al. (1983). The longer calving

Table 6. Major constraints of dairy production in urban farms.

Constraints	Small	Rank	Medium	Rank
Feed shortage	0.20	1st	0.20	1st
Feed cost	0.19	2nd	0.17	2nd
Limitation of space	0.16	3rd	0.20	1st
Shortage of AI service	0.14	4th	0.11	4th
Animal diseases	0.06	7th	0.03	7th
Milk market	0.06	8th	0.09	5th
Problem of waste management	0.10	5th	0.13	3rd
Repeated breeding of cows and heifers	0.09	6th	0.07	6th

Table 7. Major constraints of dairy production in peri-urban farms of the study area.

Constraints	Small	Rank	Medium	Rank
Feed shortage	0.19	2nd	0.18	2nd
Feed cost	0.20	1st	0.20	1st
Limitation of space	0.11	5th	0.10	5th
Shortage of AI service	0.16	3rd	0.15	3rd
Animal diseases	0.07	7th	0.07	8th
Milk market	0.13	4th	0.14	4th
Problem of waste management	0.05	8th	0.07	7th
Repeated breeding of cows and heifers	0.09	6th	0.09	6th

interval in this study might be related to poor heat detection, less access to Artificial Insemination (AI) services and poor feeding practices. There was significant difference in lactation length (P<0.01) among the different production systems. Longer estimated mean value of lactation length was obtained for dairy cows in urban area (318.8±4.13 days) than dairy cows in peri-urban areas (303.7±3.8 days). There was significant difference (P<0.01) in lactation length across the different herd size groups. The mean reported lactation length obtained in this study was shorter than 11.2 and 10.8 months reported for crossbred cows in urban and peri-urban farms, respectively (Yitaye, 2008). The overall estimated mean lactation length of 311.3±2.8 days in the current report was longer than the ideal lactation length of 305 days.

Constraints of dairy production

The respondents indicated that the availability of crop residue is limited to few months of the year. Feed shortage was critical during the end of main rainy season (September to November) which might be related to shortage of wheat straw, the major roughage feed resource in the study area. This finding is in agreement with the report of Zewdie (2010) who reported feed shortage as the major problem of livestock production in Central rift valley of Ethiopia. Limitation of space was the second major constraint of medium sized urban dairy farms. About 93.3% of the interviewed dairy cattle producers in the study area run dairy farming within their own residence compound. These producers indicated that land size is among the main constraints for expanding their dairy farming. Problem of waste management was the fourth major constraint of dairy cattle production prioritized by medium scale urban dairy farm owners.

It was reported that high feed cost was prioritized as major problem of dairy production by peri-urban dairy producers. According to the respondents, the average price of wheat straw was 4 birr per container of 5 kg in December and January which increase to 8 birr in April. The interviewed dairy producers also indicated that the price of concentrate feed is increasing from time to time in the area. On the other hand, majority of the interviewed dairy producers in the peri-urban areas indicated that feed shortage as the second major problem of dairy production in the area (Table 6). It was reported that poor AI and animal health service was the third major problem prioritized by peri-urban respondents (Table 7). Respondents in peri-urban areas (Kuyera and Kerara Filicha) indicated that AI service is given by those technicians either from Shashamane or Arsi Negele which is far from the two sites. According to the respondents in the area, there was no animal health service center in Kuyera and Kerara filicha.

Conclusion

The reproductive performances of animals on both production systems and farm scales were below their expected genetic potential, where in peri-urban and small scale farm was critically low as compared to some parts of the tropics. Hence, large variation between production systems and farm scale groups showed the opportunities for further improvement with strategic management and supplementation of energy and protein rich feeds.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

Effect of plant bio-regulators on vegetative growth, yield and quality of strawberry cv. Chandler

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The results of effect of plant bio-regulators on yield and yield attributing characters of strawberry CV. Chandler showed that at 75 DAT the plant height attained maximum of 20.50 cm, spread (25.53 cm) leaf number per plant (23.00), petiole length (0.20 cm), leaf area (136.30 cm^2) and yield (356.56 g/plant) respectively, of strawberry was obtained highest with the application of GA 75 mg/L while, cycocel 750 mg/lresulted in minimum days taken to first flowering (61.66 DAT) and fruit formation (66.66 DAT). The maximum number of flowers per plant were recorded as 30.22 and number of berries (24.80) with application of GA 75 mg/L.

Key words: Chandler, *Fragaria x ananassa*, bio-regulators, physico-chemical, yield.

INTRODUCTION

The cultivated octaploid strawberry (*Fragaria x ananassa* Duch.) belongs to family Rosaceae and it is one of the most delicious, refreshing and nutritious among soft fruits of the world. Strawberry is basically a fruit plant of temperate climate, but during the recent years, there has been phenomenal increase in its area, production and cultivation in the non-traditional regions of India (Sharma and Sharma, 2004). It has happened because of standardization of modern agro-techniques and introduction of many subtropical cultivars which unprecendently returns higher capitals under subtropical conditions as well (Asrey and Jain, 2003). In India, higher return per unit area and short duration (six months) of crop have attracted large number of Indian farmers of Punjab, Haryana, Delhi, Uttarakhand and Jammu and Kashmir states.

Under Jammu sub-tropics, strawberry has recently come out as one of the most favored and profitable crop for cultivation (Bhat et al., 2005). A key point in fruit production is the manipulation of flowering to fruit production and to increase the productivity of the crops. There is a lot of information that shows how plant bio-regulators elicit biochemical changes in plants, which in turn induce vegetative and reproductive responses. Therefore, it is imperative to assess the effect of plant bio-regulators which modifies various physiological processes with the advantage to increase strawberry production. Keeping in view the need to enhance the strawberry production, the present investigation was conducted to find out the efficacy and optimum concentration of plant bio-regulators on vegetative growth and yield of strawberry cv. Chandler.

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Table 1. Initial status of soil in the experimental orchard.

Particulars	Contents
Mechanical analysis	
Sand (%)	60.0
Silt (%)	19.0
Clay (%)	21.0
Chemical analysis	
pH	6.7
Electrical conductivity ($dsm^{-1)}$)	0.20
Organic Carbon (%)	0.51
Available Nitrogen (Kg $ha^{-1)}$)	225.5
Available Phosphorus (Kg ha^{-1})	13.84
Available Potassium (Kg ha^{-1})	138.0

MATERIALS AND METHODS

The present investigation on the effect of plant bio-regulators on vegetative growth, quality and yield of strawberry (*Fragaria x ananassa* Duch.) cv. Chandler was carried out in the experimental farm of Fruit Science Division, Faculty of Agriculture, SKUAST-J, Udheywalla, Jammu during 2009 to 2010. Udheywalla is situated in the sub-tropical zone at latitude of 32.40°N and longitude of 74.54°E. The altitude of the place is 300 m from mean sea level. The winter months experience mild to severe cold and temperature ranges from 6.5 to 21.70°C. December is the coldest month and minimum temperature goes low as 4.0°C, however, the maximum, minimum temperature and evaporation rate rises from March onwards. Before the commencement of this study, the plot remained fallow in the last and previous year. The fertilizers dose for strawberry was applied uniformly as per recommendation in package and practices for fruit crops by SKAUST-Jammu (Anonymous, 2006). A total of ten treatments replicated thrice were executed in randomized block design *viz.* T_1 - Gibberellic acid 50 ppm, T_2 - Gibberellic acid 75 ppm, T_3 - Gibberellic acid 100 ppm, T_4 - Naphthalene acetic acid 25ppm, T_5 - Naphthalene acetic acid 50ppm, T_6 - Naphthalene acetic acid 75 ppm, T_7 - Cycocel 500 ppm, T_8 - Cycocel 750 ppm, T_9 - Cycocel 1000 ppm, T_{10} - Control (Distilled water). The observations were recorded on plant height, spread, number of leaves and petiole length at 30, 45, 60 and 75 days after transplanting.

The observations on days taken to first flowering, days taken to fruit formation, average number of flowers per plant were recorded as floral characteristics and fruit yield was calculated in grams per plant.

RESULTS

The application of plant bio-regulators significantly influenced the plant height and spread of strawberry. In Figure 1, at 45, 60, 75 days after transplanting plant height (12.23, 17.50 and 20.50 cm) and in Figure 2, plant spread (18.80, 22.23, 25.53 cm) were obtained maximum with the application of GA 75 ppm as compared to other treatments.

Perusal of the data in Figure 3, showed that leaf numbers per plant (14.50, 20.66, 23.00 cm) was found highest with the application of GA 75 ppm at 45, 60, 75 days after transplanting, whereas, in Figure 4, petiole length was also observed highest with GA 75 ppm (6.15, 8.76 and 10.20 cm) at 45, 60, 75 DAT. The data depicted Table 2 showed that with the application of GA 75 ppm, leaf area of strawberry plants was also found maximum (136.30 cm^2) as compared to other treatments. Table 2 also showed that the application of cycocel 750 ppm effectively influenced the days taken to flowering (61.66 DAT) and fruit formation (66.66 DAT) which was statistically at par with GA 75 ppm (62.33 DAT) and (67.63 DAT) respectively (Table 1). It was observed from present investigations, that application of GA 75 ppm significantly increased the average number of flower per plant at primary, secondary and tertiary stages (7.00, 12.11 and 11.11) respectively, while total number of flower per plant (30.22) and number of berries (24.80) were recorded highest with GA75 ppm (Table 3). An inquisition of the data in the study revealed that the concentration of GA 75 ppm (356.5 g/plant) resulted in maximum fruit yield of strawberry cv. Chandler (Table 5). Based on the experimental results obtained, it may be concluded that GA 75 ppm applied at 30 days and repeated on 45 days after transplanting was found best in increasing growth and yield of strawberry cv.Chandler.

DISSCUSION

The maximum increase in plant height and spread of strawberry cv. Chandler in these treatments might be due to fact that gibberellins regulate the growth of strawberry plants by causing cell elongation in plant system (Figures 1 and 2). These results are in conformity with Pathak (1971) . This could be due to the fact that gibberellins increased the cell division, cell elongation and a corresponding increase in epidermal and parenchyma's cell length (Figure 3). These findings are in accordance with those of Guttridge and Thompson (1959) and Pathak and Singh (1976).

In Figure 4, which might be due to the fact that gibberellins cause the elongation in mature petiole of strawberry. Similar results were reported by Arney and

Table 2. Effect of plant bio-regulators on leaf area, days taken to first flowering and fruit formation of strawberry CV. Chandler.

Concentrations (ppm)	Leaf area(cm^2) per plant	Days taken (DAT)	
		First flowering	Fruit formation
GA 50	132.77	64.66	70.26
GA 75	136.30	62.33	67.63
GA 100	130.46	66.33	72.63
NAA 25	119.38	68.66	75.26
NAA 50	120.42	68.33	74.93
NAA 75	118.87	69.66	76.66
Cycocel 500	104.83	62.66	67.66
Cycocel 750	102.80	61.66	66.66
Cycocel 1000	107.83	65.33	70.33
Control	99.84	70.33	77.33
CD (0.05)	3.14	1.75	1.70

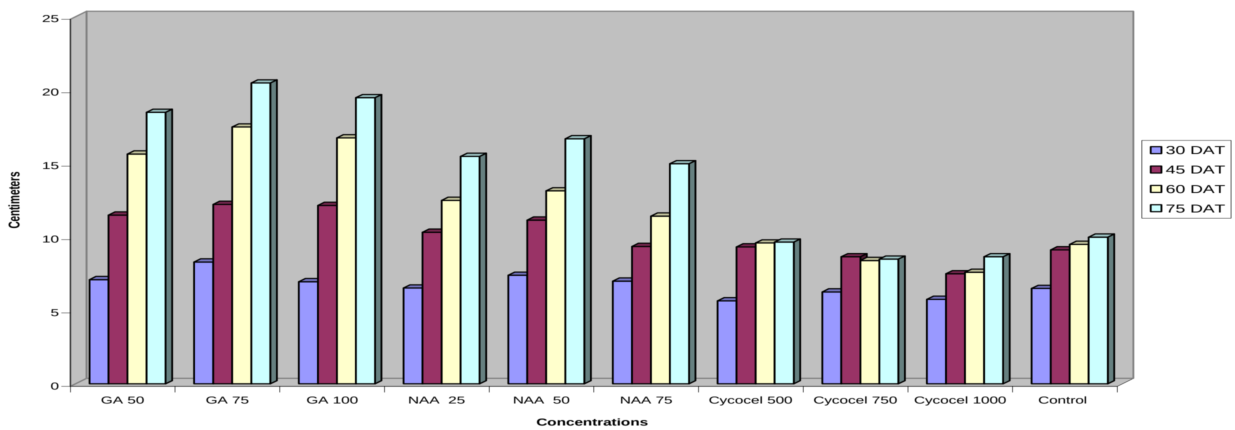

Figure 1. Effect of plant bio-regulator on plant height (cm) of straw berry.

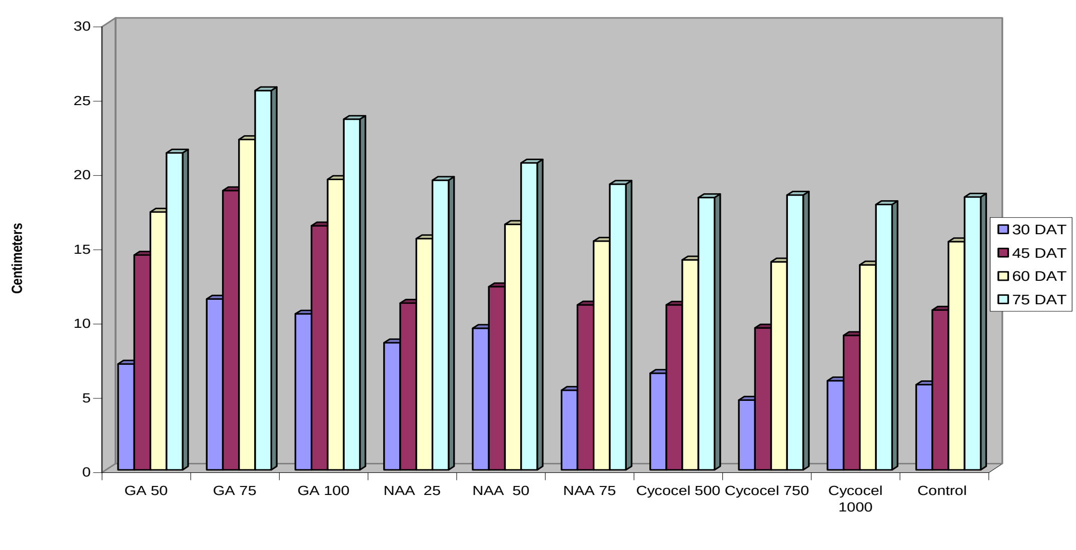

Figure 2. Effect of plant bio-regulator on plant spread (cm) of strawberry.

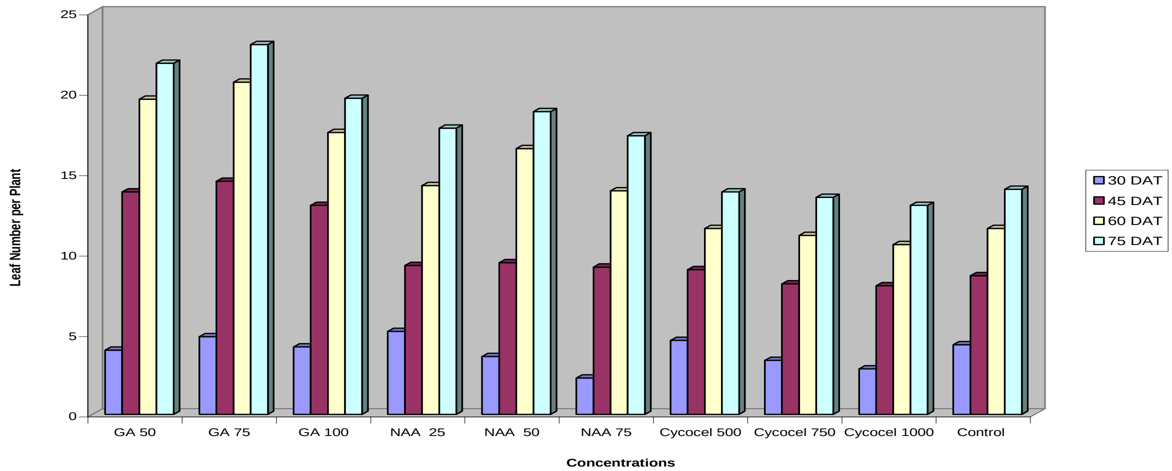

Figure 3. Effect of plant bio-regulator on leaf number per plant of strawberry.

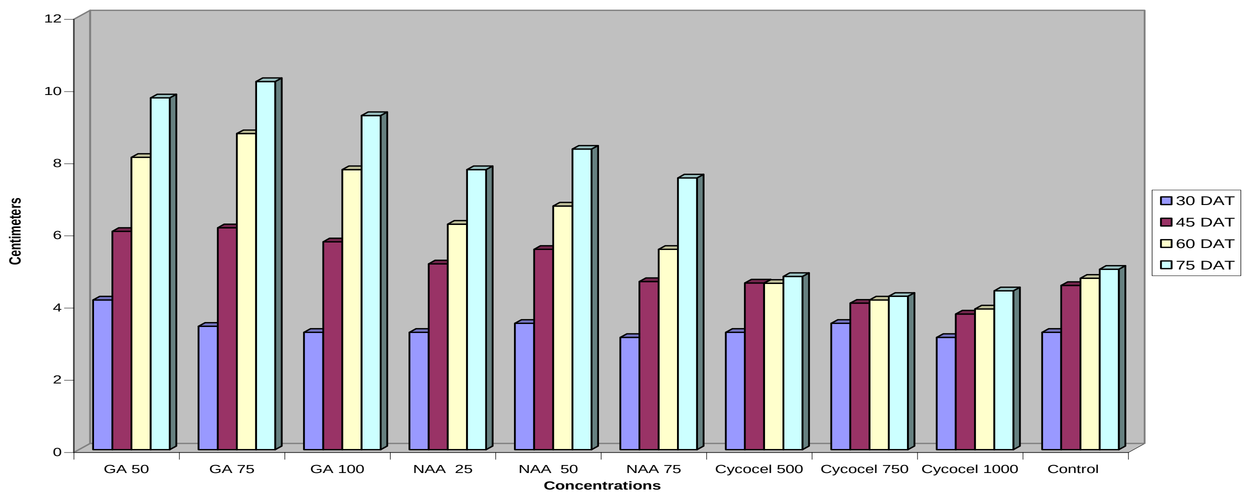

Figure 4. Effect of plant bio-regulator on petiole length (cm) of strawberry.

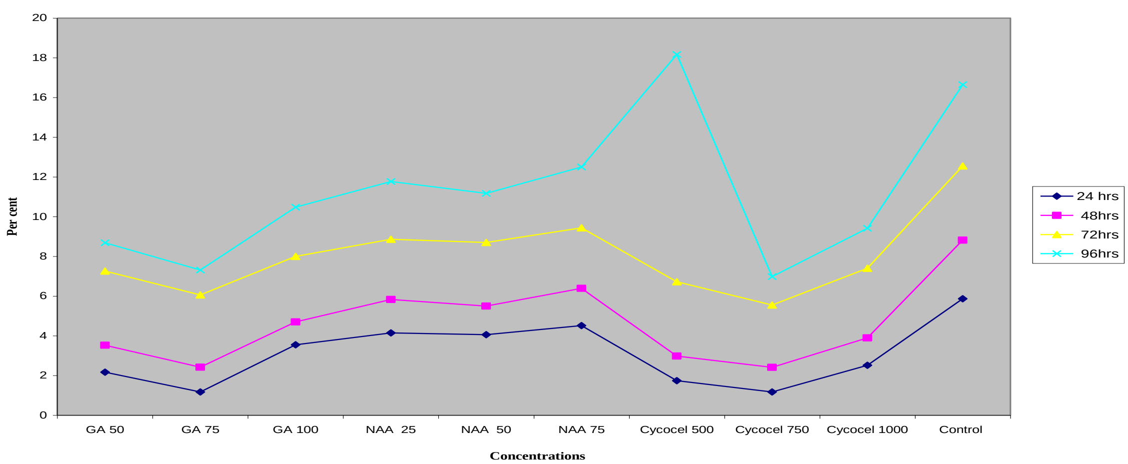

Figure 5. Effect of plant bio-regulator on percent physiological loss in weight of strawberry.

Table 3. Effect of plant bio-regulators on flowering, fruit set, number of berries/plant and fruit yield of strawberry CV. Chandler.

Concentrations (ppm)	Average number of flowers per plant			Total flowers per plant	Fruit Set (%)	No. of berries per plant	Fruit yield (gram per plant)
	Primary	Secondary	Tertiary				
GA 50	6.70	11.11	10.85	28.65	78.98	22.63	338.45
GA 75	7.00	12.11	11.11	30.22	82.06	24.80	356.56
GA 100	5.60	10.50	9.45	25.55	80.35	20.53	311.21
NAA 25	5.00	10.55	10.00	25.55	77.10	19.70	216.80
NAA 50	5.30	10.25	9.50	25.05	79.28	19.86	220.90
NAA 75	4.70	11.00	9.40	24.40	76.36	18.63	211.40
Cycocel 500	4.43	11.00	9.10	24.30	71.93	17.48	175.93
Cycocel 750	4.20	10.94	8.45	23.59	76.13	17.96	183.53
Cycocel 1000	4.03	10.32	8.00	22.35	77.49	17.32	150.70
Control	6.20	7.60	5.08	18.88	66.73	12.60	112.53
CD (0.05)	0.09	0.77	0.51	3.91	2.02	0.09	0.84

Table 4. Effect of plant bio-regulators on physical characteristics of strawberry fruits CV.Chandler.

Concentrations (ppm)	Size (mm)		Fruit weight (g)	Fruit volume (cc)	Specific gravity	No. of achene's	Juice content (%)
	Fruit length	Fruit diameter					
GA 50	37.25	27.25	16.15	16.21	0.99	381.85	94.12
GA 75	38.95	28.95	17.06	17.11	0.98	385.31	94.92
GA 100	35.87	24.44	16.05	16.12	0.99	372.61	93.08
NAA 25	32.74	22.18	15.65	15.70	0.99	335.41	92.25
NAA 50	31.79	21.78	15.53	15.59	0.99	351.72	92.89
NAA 75	30.45	20.45	15.25	15.31	0.99	319.72	92.15
Cycocel 500	37.45	27.45	16.65	16.71	0.99	382.51	94.45
Cycocel 750	39.19	29.15	17.12	17.25	0.98	385.50	95.00
Cycocel 1000	36.66	26.96	16.25	16.29	0.99	375.52	93.65
Control	29.35	20.33	12.44	12.45	0.94	291.92	85.59
CD (0.05)	0.32	0.55	1.73	1.76	0.03	0.82	0.55

Orenden (1965). It might be due to increase in cell division and cell elongation in sub-apical meristems of strawberry (Table 2). These results are in line to that ofPathak and Singh (1976).

The effect may be due to the early flowering and fruiting by blocking gibberellic synthesis. Similar results are in accordance with Sachs and Kofranek (1963) and Pathak and Singh (1976).

In Table 3, Gibberellins applied at either time have affected the initiation and duration of flowering season. Duration of flowering largely depends on the time of application of plant bio-

Table 5. Effect of plant bio-regulators on chemical characteristics of strawberry fruits CV.Chandler.

Concentrations (ppm)	TSS (^{0}Brix)	Titratable acidity (%)	TSS/Acid ratio	Ascorbic acid (mg/100g pulp)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)
GA 50	6.61	0.78	8.47	64.08	7.08	4.37	2.57
GA 75	7.06	0.80	8.82	66.03	7.82	4.51	3.14
GA 100	6.41	0.81	7.91	63.21	6.92	4.45	2.34
NAA 25	6.19	0.84	7.30	60.07	6.75	4.28	2.34
NAA 50	6.26	0.83	7.50	60.46	6.81	4.31	2.37
NAA 75	6.11	0.84	7.20	59.23	6.71	4.21	2.37
Cycocel 500	6.92	0.75	9.20	64.76	7.47	4.46	2.85
Cycocel 750	7.08	0.75	9.40	71.36	7.87	4.56	3.14
Cycocel 1000	6.51	0.76	8.50	63.47	6.96	4.41	2.42
Control	6.09	0.75	8.12	58.29	6.15	4.08	1.96
CD (0.05)	0.02	0.02	0.72	2.18	0.02	0.02	0.56

regulators which hastened the flowering period when applied about a month before the appearance of flower buds and showed an increase in secondary flowering because of temperature rise.

These findings are substantiated with the observations of Singh and Singh (2006) and Kappel and Donald (2007). Gibberellic acid causes the production of large number of flowers with rapid elongation of peduncle, leading to full development of flower buds having all reproductive parts functional which increases the fruit set and number of berries per plant. It could also be due to the fact that GA application accelerated the development of differentiated inflorescence (Table 5). Similar results are reported by Ozgvuen and Kaska (1990) and Parouissi et al. (2002). The yield attributes on the sink capacity of crop is determined by its vegetative growth throughout the life cycle of lants. Vigorous growth is associated with higher sink capacity of a crop.The higher yield might be due to formation of more metabolites by large leaves in these plants resulting in bumper flowering, fruit setting besides better vegetative growth. These results are in agreement with Sharma and Singh (1990) and Anwar et al. (1990).

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Full Length Research Paper

Soil water crop modeling for decision support in millet-based systems in the Sahel: a challenge

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Food insecurity in the Sahelian environment was extensively shown to be a result of low soil fertility and high climate risks. But decisions and recommendations made from the great wealth of research have little been adopted by farmers. Soil water crop models (SWCM) can assist researchers and development actors in this environment if they can appropriately deal with the constraints and mainly farmers' agricultural development goals. We reviewed the Sahelian agricultural constraints and farmer management practices with an emphasis on Niger and pearl millet. Significant results derived from research works to improve crop productivity are presented and analyzed with regard to the main agricultural constraints. Potential and currently used SWCMs are presented and compared for relevance for use in such a particular environment for decision support (DS). This shows that crop modeling in millet-based agricultural system of the Sahel should be addressed with an integrated approach that can handle the multiple and usually connected agricultural constraints of the region: low soil fertility and spatial variability, time and space rainfall variability. Recommendations were made regarding the relevant and minimum aspects that SWCM should take into account for a successful and reliable use for DS in the complex Sahelian environment.

Key words: Rainfall variability, simulation, nutrients, climate change, climatic risks, soil fertility.

INTRODUCTION

Smallholder farmers in the Sahelian zone of sub-Saharan Africa are facing difficult times as a result of productivity levels that are often low. Millet grain yields are often below 500 kg ha-1 (De Rouw, 2004). Crop yields are strongly dependent on, and constrained by what has been recently recognized (after many decades of blaming only water stress) as the most important asset- soil fertility (Struif Bontkes and Wopereis, 2003). The unfavorable climate and low fertility create intense pressure on land even at relatively low population densities (Reardon et al., 1997). Decision making have long been derived from the great wealth of research undertaken in the area but these constraints are still impeding the development of sahelian farmers'

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agricultural systems. There is a need for tools that can support decision making. Agricultural decision support tools (DSTs) integrate information or knowledge about soil, climate, crops, and management for making better decisions about crop production and food security. In the Sahel such DSTs can assist with the diagnosis and analysis of problems and opportunities related to water, soil fertility, and farmers endogenous practices. Several DSTs have been developed over the past decades; they range from simple best-bet options tables to sophisticated computer models (Struif Bontkes and Wopereis, 2003).

A computer model is a simplified representation of reality with which we can compute outcomes without having to perform actual experiments. The soil-water-crop models (SWCM) are computer models that can be used to predict crop yield under different management strategies, as well as individual land properties or characteristics that are important components of yield, such as moisture supply, nutrient supply, and radiation balance etc. Giving a comprehensive list of possible applications of SWCMs as DS is impossible because DS is an art of the user and mostly depends on the specific problem under study. Known applications are diverse and include crop managements (rotation, fallow), soil fertility management, water management, climate variability and risk analysis, climate adaptation, weed, pest, disease management etc. But an interesting SWCM to be used for DS should at least comply with two main criteria: 1) suitability for the target environment and 2) appropriateness for the intended purpose (CLIMAG-WA, 2002). The use of SWCM for DS is widely practiced for many regions and crops in the world but in the sahelian millet-based systems it is still far from common. To improve this situation, this review paper first analyzes the agricultural constraints for millet-based systems in the Sahelian region with respect to local farmers' practices and research outcomes. Then an overview of potential or currently used SWCMs in semi-arid Africa is given. And finally the role that these models may play in such an environment is discussed.

Main agricultural constraints in millet-based cropping systems in the Sahel

Rainfall uncertainty and variability in time and space

The general atmospheric circulation is a major factor influencing climate variation in west Africa. In Niger, the single-peak rainy season occurs in the period from May to September, with the remainder of the year dry. The length of the rainy season ranges from 60 days (250 mm year^{-1} isohyet) to 120 days (750 mm year^{-1} isohyet). Millet is grown throughout the semi-arid zone, but is dominant within the 250-750 mm year^{-1} zone (Hoogmoed and Klaij, 1990). The annual potential evapotranspiration is high (2000 – 2300 mm year^{-1}) (Sivakumar et al., 1993).

Moreover, a long term rainfall trend towards aridification was reported especially for northern rainfall stations and a comparison of different annual rainfall datasets shows that the isohyets have shifted 100-150 km southward since the 1960s (Sivakumar et al., 1993). A close relationship between the Sahelian rainfall decrease and the reduction in the number of rainy days has been confirmed by Le Barbé and Lebel (1997). They observed a decrease in both the seasonal amount and number of rainfall events of about 25%. But recently, this trend towards aridification became a very controversial issue. While some authors reported the drought to be ending since the 1990 (e.g., Ozer et al., 2003), or being simply an artifact of changing station networks (Chappell and Agnew, 2004) others as L'hote et al. (2002, 2003), Dai et al. (2004) and Hulme (2001) argued it to be real and continuing.

Beside the long term trend, the temporal variability of rainfall is very high on the annual, monthly and daily time scales. The monthly rainfall variability is more distinct since rainfall occurs only during the 3 to 5 summer months. More crucial to agriculture is the daily variability. The average amount of rain per rainy day increases from 9.7 to 14.4 mm during the course of the rainy season, while the standard deviation increased at the same time from 7.6 to 11.1 mm. The mean duration between successive rain events progressively decreases during the wet season from 6 to 2 days. Mean maxima per rainy day in July and August are 45 and 48 mm day^{-1}, respectively (Sivakumar et al., 1993).

The Sahelian zone is characterized by a strong North-South annual rainfall gradient, with 1 mm decrease on average for every km. Beside this general latidunal trend, annual differences of 200 to 300 mm may occur in any directions within a radius of only 100 km. At ICRISAT Sahelian center, total annual rainfall in 1995 ranged from 440 to 553 mm over only 2.5 km distance, while in 1996 it ranges from 503 to 554 mm over 0.8 km distance which correspond to maximum gradients of 42 and 64 mm km^{-1}, respectively (Graef, 2000). The same author mentioned that single rainfall gradients may exceed 20 mm over 3.2 km distance during a single event. So spatial rainfall variability is higher at a local scale than at regional scale. The strong local scale rainfall variability is an agro-climatic risk factor that farmers have to deal with in the Sahel and farmer's fields are found to be dispersed within 1 to 5 km distance (Graef and Haigis, 2001). Akponikpè et al. (in press) using a modeling approach, confirmed the effectiveness of this farmer fields' dispersion strategy to reduce the disparity of millet yield between households each year and to increase the inter-annual yield stability at household level.

Poor and highly variable soil physical and chemical characteristics

Based on data from the Fakara region (Hiernaux and

Ayantunde, 2004) and ICRISAT Sahelian center, Sadoré, the soils were classified as sandy, with more than 90% sand in the A horizon (West et al., 1984). Soils have a pH-water of 4.5 to 6.3, CEC of 0.8 to 7.0 meq/100g, organic matter content of 0.1 to 0.80%, total N of 100 to 300 mg kg^{-1} and total P of 0.7 to 5.5 mg kg^{-1}. Soil water at field capacity is of the order of 0.10 cm^3 cm^{-3} (Klaij and Vachaud, 1992). High variability were reported over short distances (2m) (e.g., Geiger and Manu, 1993; Manu et al., 1996; Rockstrom, 1999; Voortman et al., 2004).

The soils are of structureless class with high percentage of coarse sand particle (Hoogmoed and Klaij, 1990). Differences in soil properties are thought to be caused by differential wind and water erosion and deposition, growth of trees and shrubs before clearing for cultivation, trees left standing such as *Faidherbia albida*, termite activity, differential leaching, and/or human activity (including uneven application of manure, location of village sites and refuse heaps, and burning of cleared vegetation)(Miedema et al., 1994; Geiger et al., 1994; Gérard and Buerkert, 1999; De Rouw and Rajot, 2004).

Millet growth and yield variability in space and time

Millet germinates uniformly across fields, but 1 to 2 weeks after emergence, differences in growth occur (Scott-Wendt et al., 1988a). This short-range variability results in low yields in farmers' field and experiments. Using a scoring harvest technique in 1993, on a 40 x 60 m plot, grain yield in the sub-plots (4 x 5 m) at the end of the growing season ranged from 1.6 to 137.9 g m^{-2}, with an average of 63.9 g m^{-2}. The total biomass measured in the sub-plots ranged from 16.0 to 450.0 g m^{-2}, with an average value of 234.7 g m^{-2} (Scott-Wendt et al., 1988a).

Many attempts were made to explain the cause of this large millet yield variability. Some authors have observed that often, although not consistently, millet growth is better on micro-high conditions and poorer in micro-low situations (Scott-Wendt et al., 1988b; Geiger and Manu, 1993; Manu et al., 1996). Scott-Wendt et al. (1988b) investigated a transect from very poorly growing to well-growing millet and observed that low yields were correlated with high Aluminium saturation levels and lower cation levels (Ca, Mg, and K). Voortman et al. (Voortman et al., 2004) showed that the proportion of the cations (Ca, Mg, K and Na) on the exchange complex, in combination with the Al saturation profile were the main source of spatial variability at this scale where these soil properties explained 82% of the millet yield variation. They pointed out that macronutrients N, P, K explained only a modest portion of millet yield spatial variability.

Termite activity was also mentioned as another factor inducing spatial yield variability. According to Miedeman et al. (1994), good growth sites were associated with a higher level of termite-derived pedofeatures (termite infillings) and termite amended groundmass features (bridged grain microstructures).They explained this by an enrichment of soil-surface with organic matter and fine clayey material as a result of termite activity which cause a better chemical fertility status and a better water holding capacity.

In time (between seasons), yield variation were explained by rainfall pattern with the main determinants being the date of rain onset, number and length of dry spells, and water by nutrient interaction (Akponikpè et al., 2010). In fact rain onset is very wide (April to July), the average date (and standard deviation) of onset of the rainy season is 12 June (18 days) while rain stops approximately at the same time every year at 27 September (12 days), causing late sowings to suffer from end season water stress (Sivakumar, 1988, 1990). Frequent occurrence of dry spells were reported to impede on millet development and yield establishment mainly during sensitive phenology stages such as flowering and grain filling (Sivakumar, 1992; Winkel et al., 1997). Interaction between water and nutrient availability was frequently reported to explain millet yield variability between years. For instance, Gandah et al. (2000) observed that maximum yield was not observed at the same place in farmer field every year (under the same fertility practice). Christianson et al. (1990) tried to explain the millet grain yield as a function of N rate and annual or mid-season rainfall amount.

Farmer soil fertility management practices and research findings

Manure and corralling of livestock (on fields)

Smallholder farmers employ a range of technologies to enhance soil fertility, and manure is a cornerstone of many of the soil fertility management strategies they use. Manure is composed of all sort of feaces, urine, refuse fodder, vegetation added to the compost to trap urine, cooking waste and ash from cooking fire (Harris, 2002). Large cattle or small ruminant manure application is devoted to limited spots within farmers' fields and often applied (corralling livestock on field or transported farm yard manure) at very high application rates. Manure application was targeted to spots in only 30% of 307 fields surveyed by Schlecht et al. (2004) in a recent survey around Chikal, southwestern Niger.

Schlecht et al. (2004) collected data from southwestern Fulani (herders) and Zarma villages in southwestern Niger (Ticko, Kodey, Tigo-tegui, Banizoumbou) and found on corralling and manuring practices, average application rates of 12.7 to 15.5 t ha^{-1} feacal dry matter (FDM) for cattle and 6.8 to 7.2 t ha^{-1} (FDM) for sheep and goats. Average manure application rates in Chikal were much lower, varying around 3.4 t ha^{-1} and 1.3 t ha^{-1} FDM for cattle and for small ruminants. Akponikpè (2008) found 0.05 to 4.9 t ha^{-1} in corralled spots and 0.0 to 1.0 t ha^{-1} in farmyard manure spots within farmers field in the same area (Kodey, Tigo-tegui, Bagoua and Banizoumbou) in 2004. The amount application varies according to the farmer cattle herd size and the extent and spatial homogeneity of application depends on his capacity to assure a good distribution of the manure in the spots during corralling or farmyard manure transportation. Manuring of the same field or spot is normally repeated only every 3rd–5th year. In general, more farmers opt for the longer interval between applications than the shorter one (Schlecht et al., 2004).

Manure received much scientific attention (Williams, 1999; Harris, 2002; Schlecht et al., 2004). The effect of different manuring and corralling treatments on millet yield in the Sahel vary widely. Having tested from 1997 to 2001 five rates of application of cattle manure, that is, 2, 4, 6, 10, and 14 t ha^{-1} of fecal dry matter on a millet landrace, Schlecht et al. (2004) found that millet dry matter yields exceeded (on average over 4 consecutive years) the yield of the control by 779 ± 84 kg ha^{-1} of grain and 1822 ± 233 kg ha^{-1} of stover when 2 t ha^{-1} of manure were applied in the first year. The yield response of millet increased linearly with the rate of manure application in the first year, at least up to 14 t ha^{-1} of FDM. Some on-farm experiments (Tigo, southwestern Niger) showed that the residual effect of manuring was still significant 3 years after application (6 t ha^{-1} manure + 2 t ha^{-1} crop residue), with grain yields of 527 ± 56 kg DM ha^{-1} versus 298 ± 54 kg DM ha^{-1} in the control (Schlecht et al., 2004). Underlying beneficial effects of manure are increased soil porosity and aggregate stability, increased water infiltration and water holding capacity, decreased eolian soil losses, increased SOM, pH, CEC and nutrient availability (e.g., Bationo and Mokwunye, 1991a; Buerkert and Hiernaux, 1998; Schlecht et al., 2004). But the quality of manure produced by livestock and their effect on crop vary according to their diet (Powell et al., 1994; Tittonell et al., 2007). Other works have pointed out the beneficial effect associated with the application of urine during corralling (Powell et al., 1998; Sangaré et al., 2002).

Large manure application rates usually results in high nutrient loss on the acidic and sandy soil of Niger. On average, 1070 kg ha^{-1} of C, 91 kg ha^{-1} of N, 19 kg ha^{-1} of P were leached to depth between 1.5 and 2 m at high rates (9 to 10 t ha^{-1}) of manure application (Brouwer and Powell, 1998).

They suggested application to be less than 2.8 t ha^{-1} on topographical lows (prone to high run-on and rainfall infiltration) and 2.5 t ha^{-1} on higher parts (prone to runoff and low rainfall infiltration) of farmer's field. But these recommendations do not take into account the highly variable quality of the manure (Harris, 2002) and its low availability in the area. One strategy to increase the nutrient efficiency, well known to farmers but labour demanding, is the placement of the manure in planting pits (zaï) (Fatondji, 2002; Fatondji et al., 2006).

Crop residues

Traditionally farmer remove millet residues from farms, after grain harvest, for household uses (fencing, fuel, animal feeding, bed or granary making) or sell them to herders (Baidu-Forson, 1995; Bationo et al., 1995). So little crop residues are left on farms. Schlecht and Buerkert (2004) found in a recent survey in Chikal territory, southwestern Niger that mulching of crop residues was mainly practiced to fight wind erosion but was restricted to 36% of 307 individual farmers' fields given the alternative uses of straw. Quantities of stover found on farms in the Sahel before millet sowing are less than 800 kg ha^{-1} and mostly inadequate for effective mulching (Baidu-Forson, 1995).

As it is encountered within farmer field prior to sowing, crop residue has benefited from extended research attention. Especially long-term but also short-term application of crop residue (mulching) increases pearl millet yield, whereas their omission decreases yield immediately. For Sahelian climatic conditions, the sandy soils of western Niger and application rates up to 4 t ha^{-1}, no depressive effect of crop residue on millet yield has ever been reported.

Incorporation of crop residues gave higher yield compared to mulching or burning (Rebafka et al., 1994). The mechanisms responsible for the positive effect of crop residue on crop are physical and chemical. Physical effects comprise: reduced wind and erosion effect on nutrient that enhance seedling emergence and early growth (Michels et al., 1995; Bielders et al., 2000, 2001, 2002; Buerkert et al., 2000), reduction in surface crusting, increase formation of stable aggregates improving soil porosity and water infiltration (Hoogmoed and Stroosnijder, 1984; Buerkert and Stern, 1995) and a decrease in soil surface temperature (Buerkert and Lamers, 1999; Buerkert et al., 2000). Chemical mulching effects are related to: (1) increase exchangeable base content and cation exchange capacity (CEC), lower Al saturation, increase in plant available phosphorus and potassium, and P mobility (Kretzschmar et al., 1991; Geiger et al., 1992; Bationo et al., 1993; Hafner et al., 1993; Rebafka et al., 1994). The rate of crop residue generally tested in research or recommended are far higher than what are encountered in farmer fields before sowing and even exceed annual stover yield, which raises questions about their relevance.

Mineral fertilizer

Millet-based farming system in the Sahel is characterized by no or low inputs of fertilizer. Farmers usually mix small quantities of fertilizer with seed at sowing. Because of the low availability of crop residue and manure in the Sahel, more attention was given by research to mineral fertilizer use in order to alleviate soil fertility constraints. Although some authors have reported large responses to K fertilizer (Rebafka et al., 1994), mineral fertilizer strategies have generally focused on satisfying plant N and P requirements, the two most limiting nutrients (Bationo et al., 2003). There is no positive response to N unless adequate P is supplied (Buerkert and Stern, 1995; Buerkert et al., 2001). There were many research works done to prove the beneficial effect of N and manly P fertilizer in the area (e.g., Christianson et al., 1990; Bationo et al., 1992; Subbarao et al., 2000; Bationo and Ntare, 2000; Buerkert et al., 2001; Yamoah et al., 2002). Single superphosphate (SSP) applied annually at 13 kg P ha^{-1} effectively removed P deficiency on most cases. Rockphosphate (RP) from various regional sources (RP compacted with soluble fertilizer and partially acidulated phosphate rock (PAPR)) have also been tested and shown to vary widely in their efficiency (Bationo et al., 1990a; Bationo and Mokwunye, 1991b). Phosphorus-induced yield increases in millet have been shown to substantially increase with N application. Most research examined the immediate millet response of single or repeated application of soluble N and P and little is known about residual effects on plant growth over time, although this is crucial to predict adoption by smallholder farmers (Schlecht et al., 2006). Moreover there is evidence that on weakly buffered Sahelian soils the use of mineral fertilizers may lead to rapid decrease in soil organic matter (SOM) and pH, thereby detrimentally affecting millet production. To be sustainable, any long-term application of mineral fertilizers to Sahelian soils will need to be combined with the application of organic matter.

Combined organic amendment and mineral fertilizer

Although the effectiveness of manure, crop residue or fertilizers for improving soil fertility and crop yields has been demonstrated repeatedly through on-station and on-farm trials (e.g., Bationo and Mokwunye, 1991b; Brouwer and Powell, 1998), all these sources are limited for farmers' use by either availability (Palm et al., 1997), competing uses (Bationo et al., 1995; Lamers et al., 1998) and price or financial risk (Shapiro and Sanders, 1998). Hence, an integrated nutrient management (INM) which relies on the use of multiple sources of nutrients sources (various organic and mineral fertilizer) is a necessity in order to achieve productive and sustainable agricultural systems (Palm et al., 1997; Kimani et al., 2003).

Additive, but also synergetic (more than proportional) effects have been reported in the literature as a result of the combined use of organic and inorganic amendments (e.g., Bationo et al., 1993; Hafner et al., 1993; Kimetu et al., 2004; Akponikpè et al., 2008). In Niger, phosphorus use efficiency for millet (kg grain/kg applied P) was increased from 46 on plots fertilized with inorganic P to 86 on plots amended with inorganic N and P and millet crop residue (Bationo et al., 2003). On average over a 9-year experiment, Yamoah et al. (2002) reported that millet grain yield increased from 320 kg ha^{-1} on control plots to 700, 900 and 1510 kg ha^{-1} on plots amended with residue, N & P fertilizer and residue + N & P fertilizer, respectively. Similar trends were reported for millet stover yield. Water use efficiency was raised from 0.78 kg grain ha^{-1} mm^{-1} for the control to 3.61 kg ha^{-1} mm^{-1} for the residue+fertilizer plots. Fertilizer use efficiency (kg grain kg^{-1} fertilizer) was 13.5 for the fertilized plots and increased to 27.6 upon the addition of residue. Yamoah et al. (2002) concluded that the residue+fertilizer treatment had the highest sustainability yield index.

These synergetic effects may result from the side effects of using organic fertilizers, besides their role as nutrient providers: P mobility enhancement, decrease in exchangeable Al, enhancement of root growth, decreased surface temperature and soil penetration resistance, and soil protection against wind erosion (Bielders et al., 2000; Buerkert et al., 2000). A specific effect of INM is to also to maximize nutrient use efficiency (Kimani et al., 2003). In millet-based rainfed systems, this goes along with a strong increase in water use efficiency, as seasonal cumulative evapotranspiration is little affected by fertility management practices (Payne, 2000). Whereas fertilizers release their nutrients rather rapidly, manure or residue act as slow release fertilizers. In addition, they are a source of multiple nutrients, including micronutrients, supply carbon for soil micro-organisms involved in nutrient cycling, and may improve soil physical and chemical quality (Buerkert et al., 2000; Esse et al., 2001; Harris, 2002). The use of either crop residue or manure can buffer soil acidification resulting from fertilizer use, thereby enhancing fertilizer use efficiency by preventing P immobilization (e.g., Hafner et al., 1993).

Analysis of traditional and proposed technologies and need of decision support tools

Sustainability of research proposed versus traditional technologies

Subbarao et al. (2000) studied the long-term effects of tillage, phosphorus fertilization and crop rotation on pearl millet productivity at Sadoré and found that the traditional system was more stable although it had the lowest yield. In another case study combining 13 alternative technologies ranging from sole millet or intercropping, improved cultivars, P fertilizer application, tillage and rotation Subbarao et al. (2000) found again the traditional production system to be more stable. As the degree of intensification increased in the Sahel, the stability of the production system declines (Subbarao et al., 1999). De Rouw (2004) found similar results regarding plant densities as conventional low density planting did not produce high yields as frequently as higher densities under favorable conditions. However, there was less crop failure under harsh conditions with low density sowing, although lower average grain yields were realized.

The Sahel: A complex agricultural research environment

Many authors have emphasized that the interpretation of experimental research is often difficult because the soils which have developed in coversand materials, although uniformly very sandy, exhibit a great spatial variability within distances as short as few meters (Voortman et al., 2004). The local soil variability leads to large variations among replications of experimental treatments. Moreover annual rainfall variability causes research results not to be consistent from year to year and there is a poor comparability of results across locations and climatic conditions (Schlecht et al., 2006).

Level of adoption of proposed technologies and need for decision support tools

Research efforts have provided the foundation for extension in Sahelian countries. In Niger, for example, extension has formulated a set of proposals (Reddy, 1988; Klaij et al., 1994): (i) Higher plant densities were recommended as a means to achieve higher yields at low cost. However, significant increases in density should only be made in conjunction with mineral fertilizer use; (ii) modest quantities of N and P should be applied next to individual hills for their most effective use and this increases the risk of crop failure in poor rainfall years (De Rouw, 2004); (iii) selected short cycle cultivars should replace the local landraces, especially if the rains are late. As a consequence, these proposals were tested further in suitable rainfall zones throughout Niger (INRAN, 1990) and were applied in many development projects (Ukkerman and Hama, 1995).

However, these recommendations have not been widely adopted. Selected cultivars, mineral fertilizers, and cropping practices such as higher stand density have been used by only a few farmers within the development projects and none else (Abdoulaye and Lowenberg-Deboer, 2000). Fertilizer recommendations are often based on nutrient response trials limited to a few years and locations. Sometimes standard or ‘blanket” recommendations are applied for whole agro-ecological regions or even the whole country (Vanlauwe and Giller, 2006). It is hard, in this sense, for extension services to match research findings to farmers local site conditions which may not be comparable to on-station or on-farm conditions found elsewhere. Recommendations need to be more flexible. In addition, the difference in priorities between researchers, who aim to improve yields in average years, and Sahelian farmers, who seek to reduce the frequency of crop failure, could explain the non-adoption of most innovations because the risks of yield losses were not reduced (De Rouw, 2004). Farmers are familiar with, and apply soil fertility improvement techniques of mineral fertilizer (including rock phosphate), crop residue, cattle and farmyard manure and crop rotation. According to Enyong et al. (1999) farmers attitudes to and rationales behind adoption are influenced by the availability and land use policies and available labor resources, food security concerns, perceived profitability, contribution to sustainability and access to information. But some of the factors are beyond farmers’ control and require a broad and integrated effort from research, extension and government to promote the use of the fertility improvement technologies in the region.

Given the complexity and heterogeneity of the millet-based cropping systems in the Sahel, the situation undoubtedly calls for comprehensive, easy and low cost tools. DSTs such as numerical soil-water-crop simulation models could play a key role, helping in saving time and money from long years of field/station experiments and capitalizing on farmers’ local knowledge and existing research findings.

1. State of the art of soil-water-crop modeling in the semi-arid Africa SWCMs will be shortly described and experience of their use in the Sahelian context will be presented highlighting successes and shortcomings. SWCMs are presented following chronological order of use in the crop yield modeling science. Statistical models have been used for yield prediction for several decades, water-balance models took up the challenge by tackling water requirement satisfaction in relation to crop production. More recently efforts were made to take into account processes related to plant nutrient interactions. Although potentially important, modeling of biotic stresses (weed, pests, diseases, etc) will not be discussed here.

Empirical-statistical models

This approach goes back to the 1930’s and is the oldest form of crop modeling. Yield is predicted as a statistical function of observed key environmental characteristic averaged over part or all of the growing season (e.g., Thompson, 1986; Dourado-Neto et al., 1998a, b). The statistical functions are usually developed by simple/multiple regression techniques (stepwise linear, ordinary least squares (OLS) and maximum likelihood estimation (ML). These environmental characteristics are typically climate (precipitation, solar radiation and temperature, evapotranspiration averaged over the growing season or over specific periods) and soil (nutrient status, organic matter content, particle -size distribution). Although these models may have a role under particular circumstances, they have been largely replaced by models that are more or less dynamic, at least with respect to the soil water balance. Examples in the millet-based Sahelian system explained millet grain yield as a function of N rate and annual or mid-season rainfall (Christianson et al., 1990); N rate, plant density and rainfall during particular crop phase (Bationo et al., 1990b), N, P and /or K rates (Fussell et al., 1987); N, P and K rates with other soil, terrain and management variables (Voortman and Brouwer, 2003). As with any empirical model, these models can only be applied in their original zone of calibration. Extrapolation to new conditions is not warranted. Although these models may have a role under particular circumstances, they have been largely replaced by models that are more or less dynamic, at least with respect to the soil water balance.

Water-balance (stress index models)

Due to soil constraints for efficient water use, and the critical importance of available water to food security in semi-arid West Africa, considerable regional effort has been devoted to water balance studies and models. Dynamic water balance models simulate infiltration, runoff, drainage and evaporation from soil. Simple descriptions of crop canopy development permit calculation of transpiration (CLIMAG-WA, 2002). A stress index such as the time integral of the ratio of actual to potential transpiration can be related empirically to reduction of growth and yield. The stress index approach (Doorenbos and Pruitt, 1977) is not fundamentally different from that used in dynamic process crop models. Canopy characteristics are taken as an input rather than a dynamic state variable greatly simplifies the model but also does not permit to take into account feedback mechanisms, such as early-season water stress and later-season demand. Water balance - stress index models have been applied to a broader range of scales than process models. They are applied in West African countries for agrometeorological and food security assessments. SARRAH-based models (Système d'Analyse Régional des Risques Agroclimatiques-Habillé) typically and deterministically simulate attainable yields (water-limited under optimal soil fertility condition) at the field scale, but may also be stochastic and operate at variable temporal and spatial scales (Samba, 1998; Baron et al., 1999). Extrapolation from plot to region is done by AGRHYMET (Niamey) for agro-meteorological forecasting using the DHC system ("Diagnostic Hydrique des Cultures"), which includes SARRA as a component (Samba, 1998). A specific sub-model was developed for millet (SARRA-millet or SARRAH-mil) and was structured to enable such applications as well, but with greater physiological detail. It is frequently used by agronomists and agro-meteorologists working in the Sahel. It has been used for zoning and risk analyses (Affholder, 1997; Baron et al., 1999; Sultan et al., 2005a), to analyze the impact of regional climatic variability on millet yield (Sultan et al., 2005b) and to predict agricultural plot yield based on Global Circulation Model output (Baron et al., 2005).

Dynamic process models

Over the past 25 years, many individual modelers and collaborative groups have attempted to develop models that simulate the growth of crops, along with associated phenomena that influence crop growth such as water and solute movement in soils. Dynamic process models are then those which simulate through time (usually on a daily or sub-daily time step) the ecological and physiological processes of crop growth, development and interaction with the environment. Experience has led to a distinction between mechanistic models that try to capture our understanding of the mechanisms behind subsets of those processes with the primary objective to advance our understanding, and functional models that make useful simplifications so that data requirements and the robustness of predictions are appropriate for a rather broad range of practical applications (CLIMAG-WA, 2002). A short overview will be given for the five most promising and widely known ones (irrespective of age or importance): "School of de Wit", APSIM, DSSAT, STICS, Cropsyst. Examples of applications in semi-arid Africa will be given and completed with other applications in Africa in general because of the very few crop modeling works in the Sahel.

"School of de Wit" models

The modeling group from Wageningen Agricultural University, The Netherlands – nicknamed the "School of de Wit" in honor of their early crop modeling pioneer – has taken a rather different approach (Bouman et al., 1996). Instead of developing comprehensive, general purpose models, they have emphasized application-dependent models, and have developed tools to facilitate rapid development of relatively simple models(CLIMAG-WA, 2002). Yet we can identify an evolving family of crop models that includes SUCROS, MACROS and WOFOST. A model for sorghum, millet and maize with a tipping-bucket soil water balance model has been developed for use in the Soudano-Sahelian region (Bazi et al., 1995).

APSIM

The agricultural production systems simulator (APSIM) is a modular modeling framework that has been developed by the Agricultural Production Systems Research Unit in

Table 1. List of various types of applications of the APSIM crop models in Africa and example references that describe these applications in detail.

Type of application	Crop, Climatic zone and country	References
Low input farming systems in	Maize, grain legumes (Dry and wet Zimbabwe)	Shamudzarira et al. (2000), Shamudzarira and Robertson (2002), Chivenge et al. (2004)
N and P release from organic source	Maize (semi-arid and Wet Kenya)	Kinyangi et al. (2004), Micheni et al.(2004)
Water-soil fertility management	Sorghum (Semi-arid Ghana) Millet (Sahel, Niger)	Kpongor (2007) ,MacCarthy et al., (2009) Akponikpè (2008), Akponikpè et al. (2010)
Agro-climatic risk management	Millet (Sahel, Niger)	Akponikpè et al. (2011), Akponikpè (2008); Akponikpè et al. (2010), Akponikpè et al. (2011), Tidjani and Akponikpe (2012), Tachie-Obeng et al. (2013)

Australia (Keating et al., 2003). APSIM was developed to simulate biophysical process in farming systems, in particular where there is interest in the economic and ecological outcomes of management practices in the face of climatic risk. It is a modular framework. Its modules include a diverse range of crops, pastures and trees, soil processes including water balance, N and P transformations, soil pH, erosion and a full range of management controls (manure, fertilizer, weeding, irrigation, etc). APSIM has been used in a broad range of applications, including support for on-farm decision making, farming systems design for production or resource management objectives, assessment of the value of seasonal climate forecasting, analysis of supply chain issues in agribusiness activities, development of waste management guidelines, risk assessment for government policy making and as a guide to research and education activity (Keating et al., 2003). APSIM implements a high degree of modularity of the various modules and processes (Mccown et al., 1996). The initial motivation was to improve flexibility to model cropping systems and a wider range of soil and management processes. It was developed primarily for Australia's agricultural industry, but now supports a variety of applications in many parts of the world. As a result of a relatively high level of funding and scientific and development staffing, model development is more active for APSIM than for any of the other families of crop models. Recently the APSIM-millet model was validated for the Sahelian soils, millet cultivars and climate conditions (Akponikpè, 2008). Multiple DS applications were also implemented ranging from nutrients to climate risk management (Akponikpè, 2008; Akponikpè et al., 2010, Akponikpè et al., 2011, Tidjani and Akponikpe, 2012, Tachie-Obeng et al., 2013). It has been used in semi-arid Africa for other various applications (Table 1) and many other studies are in progress in the region.

DSSAT (CERES and CROPGRO)

The DS system for agrotechnology transfer Decision Support System for Agrotechnology Transfer (DSSAT) (Jones et al., 2003) has been in use for the last 20 years by researchers worldwide. DSSAT is a product of the decade-long (1982-1993) IBSNAT (International Benchmark Sites Network for Agrotechnology Transfer) project. The basis for the new DSSAT cropping system model (CSM) design is a modular structure in which components separate along scientific discipline lines and are structured to allow easy replacement or addition of modules. It has one Soil module, a Crop Template module which can simulate different crops by defining species input files, an interface to add individual crop models if they have the same design and interface, a Weather module, and a module for dealing with competition for light and water among the soil, plants, and atmosphere. It is also designed for incorporation into various application packages, ranging from those that help researchers adapt and test the CSM to those that operate the DSSAT-CSM to simulate production over time and space for different purposes.

Within DSSAT, the relevant models are CERES, which includes the dryland cereal crops, and CROPGRO for grain legumes (Jones et al., 2003). CERES and CROPGRO (grain legumes) differ considerably in their level of detail, degree of modularity and underlying physiological assumptions. Both CERES models and CROPGRO have undergone some testing and application in semi-arid West Africa (Table 2). Jagtap et al. (1999) describe decision applications in a more sub-humid environment in Nigeria. Thornton et al. (1997) developed a prototype GIS-based, real-time yield forecasting system for Burkina Faso that uses CERES-Millet and satellite-derived precipitation estimates combined with historic weather data series. CROPGRO-Peanut performed well in recent experiments in northern Benin (Adomou et al., 2005) and Ghana (Naab et al., 2004) taking into account disease damage. For an experiment at Tara, Niger, CERES-Millet substantially over predicted LAI, biomass, grain yield and soil water content (Fechter et al., 1991). On the other hand, Naab et al. (2004) obtained good predictions of soil water contents and use in groundnut experiments in northern

Table 2. List of various types of applications of the DSSAT crop models in Africa and example references that describe these applications in detail.

Type of application	Crop (Climatic zone and country)	References
Crop management	Millet (semi-arid Niger), Maize (semi-arid Kenya), Maize (Rwanda)	Fechter et al. (Fechter et al., 1991), Fechter (1993), Mbabaliye and Wojtkowski (1994), Wafula (1995), Soler et al. (2008)
Fertilizer management	Maize (Dry and wet Nigeria), maize (Malawi)	Jagtap (1999), Thornton et al. (1997), MacCarthy et al. (2012); Adamou et al. (2012),
Irrigation and water management	Wheat (Egypt), Wheat (Zimbabwe), Millet under Zaï	Kamel et al. (1995), Macrobert and Savage (1998); Fatondji et al. (2012).
Climate change and variability	Maize (Zimbabwe)	Muchena and Iglesia (1995), Phillips et al. (1998)
Risk analysis	Millet (Semi-arid Niger) ; Maize and pasture (Dryland southern Africa)	Bley et al. (1991), Jones and Thornton (2002)
Food security	Millet, (Soudano-Sahelian and Semi-arid Burkina Faso); Maize (South-Africa)	Thornton et al. (1997), Dupisani (1987)

Ghana when values of these hydrological properties were based on field measurements. Recently Soler et al. (2008) used this model for optimal planting date determination for millet in the Sahel. The DSSAT model was used for a better process understanding for several agricultural processes involving the integrated soil fertility management (MacCarthy et al. 2012; Adamou et al., 2012), millet response to the zaï rainwater harversting technique (Fatondji et al., 2012). Models included in DSSAT (including their predecessors) have been used in more regions and for a broader range of applications than any other family of crop models.

STICS

The 'Simulateur mulTIdisciplinaire pour les Cultures Standards' STICS is a model that has been developed at INRA (France) since 1996 (Brisson et al., 2003). It simulates crop growth as a response to soil water and nitrogen balances driven by climatic conditions. The output are both agricultural variables (yield, input use) and environmental variables (water and nitrogen losses). One of the key elements of STICS is its adaptability to various crops and this is achieved by the use of generic parameters relevant for most crops and on options in the model formalizations concerning both physiology and management that are specific for each crop (Brisson et al., 2003). Folliard et al.(2004) compared modeling of sorghum response to photoperiod to related function implemented in STICS. To our knowledge there have been no applications of this model in semi-arid west-Africa.

CropSyst

The cropping systems simulation model CropSyst (Bechini et al., 2003) implements model modularity through an object-oriented structure. The result is a relatively user-friendly and flexible simulation environment. CropSyst is one of very few dynamic crop models that incorporates pest (aphid) population dynamics and damage. Its potential use for forecasting spatial distributions of millet yields was demonstrated for Burkina Faso (Badini et al., 1997), but without experimental validation of predictions. It has recently been used for grassland productivity analysis and soil carbon in response to time-controlled rotational grazing in semi-arid Mali (Badini et al., 1997).

Which soil-crop simulation models and how they may help overcome agricultural constraints in the Sahel?

The main disadvantages of mechanistic and dynamic models approach versus simple empirical models are their complexity, the high demand in data not often available and the limited use and accessibility to stakeholders in the Sahelian region. On the other hand the complex water-nutrient-genotype interaction governing crop growth and development make empirical models inadequate, which limits the usefulness of the latter ones only to an understanding or determination of the most meaningful variables that may explain yield in experiments. Predictability of empirical models in the Sahelian environment is low which makes them unsuitable for long term system analysis. Given the complexity and heterogeneity of Sahelian production systems, the use of dynamic modeling tools seems to be a prerequisite. The reason of data availability which lead to opt for simple models, often delays interest in needed data collection.

Regarding the mechanistic and dynamic models, APSIM and DSSAT stand in good place involving most of the constraints of the millet based systems in the Sahel and benefiting from a long history of collaboration with the scientific community in the area (Table 3). But none of them provide a build-in option to explicitly account for soil spatial variability. Nevertheless this shortcoming may be accounted for by multiple point-level simulations and /or GIS combination (Akponikpè, 2008, Akponikpè et al., in press) Neither APSIM nor DSSAT are now capable

Table 3. Comparison of crop-soil simulation models according to the main agronomic yield determinants and constraints in the Sahel.

	APSIM	CERES/DSSAT	STICS / CropSyst	SARRAH
Water stress	SOILWAT cascading layer model APSWIM numerical solution of Richards' equation	SOIL cascading layer model ('tipping bucket') _	cascading layer model Richards'equation (CropSyst)	cascading layer model _
Carbon assimilation	Carbon balance	Carbon balance	Carbon balance	Carbon balance
Nitrogen stress	SOIL N Balance mineralisation, (de)nitrification, immobilization, volatilisation	Soil N Balance mineralisation (de)nitrification, immobilization, volatilisation	Soil N Balance mineralisation (de)nitrification, immobilization, volatilisation	_
Phosphorus stress	Soil P available for other crops, under development for millet	Soil P	_	_
Crops	Individual crop modules (APSIM-millet, maize, etc) Extended work on the tillering characteristic of millet	Individual crop modules (CERES-millet, maize, etc)	Many crops	Millet
Fertility management	- SurfaceOM (previously Surface, Residue) - Fertilizer	- Residue (R. and other organic matter decomposition) - Fertilizer	Fertilizer and other organic matter	_
Spatial variability	_	_	_	_
Soil Acidity	_	_	_	_
Computer code availability and licence cost	Code available on internet, free, in transition to open source development	Code available, nominal fee even for academic use	Code not available, Free	Code not available, nominal fee

of dealing with P balance, an important millet yield limiting factor in the Sahelian area. Efforts should be made to quickly overcome this shortcoming.

Recently the APSIM model benefited from an extended work on millet module calibration and mainly on its tillering characteristic (Oosterom et al., 2001a, b, 2002). The specific tillering capability of APSIM (based on millet cultivars from semi-arid India) opened the door and guidance for pioneering works of eco-physiological millet characterization in other semi-arid zones, such as the Sahel, which any other crop soil model may benefit from in the future.

Overall the use of numerical crop simulation models is complex, and hardware requirements and computation time are high and generally beyond the capability of technology-transfer specialists. In the long term, the process of perfect DS systems should evolve into simpler models such as meta-models that constitute an alternative to the use of complex SWCMs.

Conclusion

The low productivity of the Sahelian millet-based systems is due to poor soil fertility and low and uncertain rainfall conditions. A great wealth of research trials addressed the issue to alleviate the agricultural production constraints with variable results depending on year and agro-ecological environment. Recommendations drawn from research outcomes received limited farmers' interest and adoption because of various reasons (technical, institutional, difference of priority, socio-economical, etc). Several SWCMs exist and are potentially useful for application in the complex and heterogeneous Sahelian agricultural system for DS to save time, money and capitalize on past research trials and farmers local knowledge. Empirical modeling of crop response dates back to the 1930's and was followed by more or less detailed process and dynamic crop modeling development during the past 25 years. But the use of SWCM for DS is still not veritably established in the semi-arid west-Africa. Among process models, APSIM and DSSAT are the most promising and efforts are still need to improve their use and effectiveness to deal with the main agricultural constraints in the area (water, N and P management, the high variability in soil physical and chemical properties).

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Chlorophyll and macronutrients content in leaf tissue of *Musa* sp 'Prata-Anã' under fertigation

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The banana (*Musa* sp.) crop is notable for its social and economic importance in tropical and subtropical regions of world. In Brazil, despite being a main banana producer, its production is considered low, mainly due to water and nutrient shortages in soils. This fact motivated this study; so, it aimed to evaluate chlorophyll and macronutrients content in leaf tissue of banana 'Prata-Anã' (AAB) under fertigation with doses of nitrogen and potassium. It were evaluated chlorophyll *a*, *b* and total and leaf contents of nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg) and calcium (Ca) in banana trees grown in an Ultisol on the coastal tablelands of Sergipe State, Brazil. The experiment was conducted in the field, in a 4^2 factorial with four randomized blocks. Two factors with four levels were tested: nitrogen (0; 350; 700 and 1050, in kg ha^{-1} of N, as urea) and potassium (0; 400; 800 and 1200, in kg ha^{-1} of K_2O, as potassium chloride). Increasing N applied through irrigation enhances leaf nitrogen until approximately 631.08 kg ha^{-1} of N, while chlorophyll total remains constant after 250 kg ha^{-1}. Phosphorus and calcium are increased due to high doses of N, however, magnesium and potassium in the leaves are reduced. High doses of K increase leaf content of K until estimated dose of 698.07 kg ha^{-1} and reduce calcium and magnesium of banana 'Prata-Anã'.

Key words: *Musa* sp., mineral fertilizer, nutrition, photosynthetic pigments, nutrient splitting.

INTRODUCTION

Banana crop (*Musa* sp.) is notable for its social and economic importance and it is a strategic crop for global food security. It is cultivated in tropical and subtropical regions, in an area of 4.8 million ha, with an average fruit

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yield of 19 t ha^{-1}, and world production reaches 91.2 million metric ton (Furlaneto et al., 2011). Banana cultivation has a strategic role in the world food production, which is justified by its peculiar nutritional characteristics and yield potential, which can reach 100 t ha^{-1}. However, Santos et al. (2009) pointed out that the Brazilian yield is very low, due to water and nutrient shortages, mainly in the northeast of the country, where the largest production of the country is located (Fernandes et al., 2008).

Low yields are related to environmental limitations such as climate and soil fertility, and it is due to low input of technology in most of the plantations. In some plantations, however, improvements in fertilizer use, by applying the fertilizers through the irrigation water, have increased the yield. This technology has been consolidated by Teixeira et al. (2001); Duenhas et al. (2002); Guerra et al. (2004); Sousa et al. (2004) and Pinto et al. (2005), however there is a shortage of experimental data in order to improve fertigation in soils of the coastal tablelands. Monitoring nutrient dynamics is vital because nutrients act in plant growth, fruit ripening and plant senescence (Moreira and Fageria, 2009). Leaf analysis is an important tool to evaluate plant nutritional status, and is a technique that complements visual diagnosis in studying nutrient dynamics (Donato et al., 2010). Among nutrients applied through irrigation water, N and K are the most used due to their chemical and physical characteristics such as high water solubility, when urea and potassium chloride are used as their source. According to Epstein and Bloom (2006),

nitrogen is associated to organic compounds, such as amino acids, proteins, coenzymes, nucleic acids, vitamins and chlorophyll, as a constituent of their molecules. All these compounds are related to enzyme reactions and to the photosynthesis process. Similarly, potassium is a very required macronutrient for the nutrition of banana tree, because its accumulation in the plant creates an osmotic gradient that facilitates the water movement, regulating the opening and closing of stomata, playing a key role in saving water and turgidity of the cells, in carbohydrate transport and in respiration (Epstein and Bloom, 2006). Due to scarcity of studies on the nutritional effects of N and K splitting in banana, the objective of this paper was to evaluate the chlorophyll and macronutrient contents in the leaf tissue of banana 'Prata-Anã' (AAB) under fertigation with nitrogen and potassium applied through irrigation water in an Ultisol on the coastal tablelands of the northeast of Brazil.

MATERIALS AND METHODS

The experiment was established in an Ultisol on the coastal tablelands located in the Sergipe Federal University Experiment Station, in São Cristóvão County, Brazil, latitude 10°19'S; longitude 36°39'O of Greenwich, twenty meters above sea level. According to the Köppen climate classification, it is tropical with a dry season, rainfall of around 1200 mm $year^{-1}$, and a rainy season from April to September.

Soil samples were collected at 0.0 to 0.2 m depth and the following attributes were found: pH = 5.2; P^{3+} = 2.4 mg dm^{-3}; K^+ = 0.08 $cmol_c$ dm^{-3}; $Ca^{2+} + Mg^{2+}$ = 0.89 $cmol_c$ dm^{-3}; Al^{3+} = 0.2 $cmol_c$ dm^{-3}; $H^+ + Al^{3+}$ = 2.56 $cmol_c$ dm^{-3}; Na^+ = 0.055 $cmol_c$ dm^{-3}; V = 42.47%; CTC = 4.45 $cmol_c$ dm^{-3}; M.O. = 2.1 dag dm^{-3}; clay, silt and sand were 632, 296 and 72 g kg^{-1} respectively; soil density was 1.59 kg dm^{-3}; *in situ* field capacity 0.199 m^3 m^{-3} and wilting point (1500 kPa) = 0.033 m^3 m^{-3}.

The experiment was set up in a factorial 4^2 and treatments were N (0, 350, 700 and 1050 kg ha^{-1} $year^{-1}$, as urea) and K (0, 400, 800 and 1200 kg K_2O ha^{-1} $year^{-1}$, as potassium chloride) in a randomized blocks with four replications. In each plot, eight micro propagated seedlings of 'Prata-Anã' (*Musa* sp. AAB) were planted, in double rows and a spacing of 3 x 2 x 2 m. Soil was plowed and limed to reach 70% bases saturation. Two and half ton of dolomite lime was applied per ha^{-1} and incorporated to the soil at approximately 0.2 m. Planting holes with diameter and depth of 0.5 m were made by a mechanical drill.

Planting holes were fertilized with 300 g of single superphosphate, 60 g of a mixture of micronutrients FTE-BR12 (9% Zn; 1.8% B; 0.85% Cu; 3% Fe; 2.1% Mn e 0.10% Mo), 200 g of dolomite lime and 10 L of cow manure, mixed all together and applied 45 days before planting. 10 g of zinc sulphate were applied every 60 days through irrigation water (Maia et al., 2003).

In each hole, the plants in excess were cut, leaving only three of them, the mother plant, a daughter and a granddaughter plants in order to avoid competition for nutrients and water. Cutting took place up to six months when a daughter plant was selected. Plant remains were left between rows in order to act as a mulching. Weeds were controlled by Glyphosate plus 2.4-D every three months. When cutting of the leaves was performed, the bunch heart was also cut at approximately 0.15 m from the last completely formed bananas fruits. Management of pests and diseases were eliminated according to Moreira (1999).

Irrigation was implemented by compensating sprinkling with nominal flow of 94 x 10^{-5} m^3 s^{-1} (70 L h^{-1}) and irrigation management was based on monitoring of climatic data and the reference evapotranspiration was calculated by Penman-Monteith model and standardized by Allen et al. (1998). Meteorological variables were obtained from an automatic weather station, installed next to the experiment. Crop coefficient (Kc) was obtained in Maia et al. (2003). Leaf sampling for chlorophyll and macronutrients N, P, K, Mg and Ca analysis was carried out according to Martin-Prével (1980). Chlorophyll *a* and *b* (mg dm^{-2}) were obtained according to Arnon (1949), by using twenty five foliar discs. From the extracts, chlorophyll total concentration (Clt) readings were achieved at 645 and 663 nm. Afterwards, chlorophyll total concentration (µg cm^{-3}) was transformed into mg of chlorophyll dm^{-2} of leaf area (Arnon, 1949). Leaf samples were dried, ground and contents of N, P, K, Mg and Ca were obtained according to Malavolta et al. (1997).

Statistical analysis

Data were submitted to variance analysis using the F test at (p<0.05). Regression equations were adjusted and their coefficients were tested by Student (p<0.1). Pearson linear correlations also were carried out by using SAEG 9.1.

RESULTS AND DISCUSSION

Chlorophyll concentration

Chlorophylls (*a* and *b*) were reduced in the absence of nitrogen or when doses were low (Figure 1A and B). In

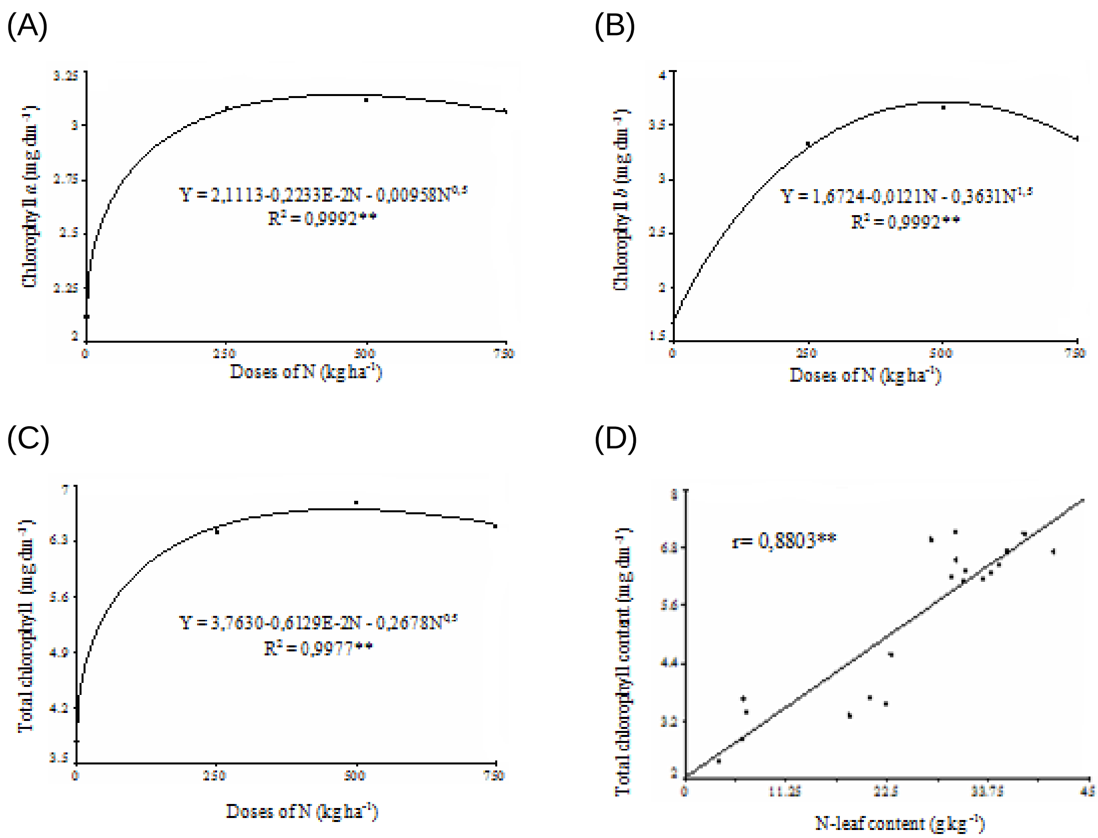

Figure 1. Effects of nitrogen applied through irrigation water on chlorophyll *a* (A), chlorophyll *b* (B), total chlorophyll (C) and correlation between N-leaf and chlorophyll (D) in banana tree leaves cv. 'Prata-Anã'.

the absence of N, chlorophyll *a* content (2.11 mg dm^{-2}) was greater than chlorophyll *b* (1.67 mg dm^{-2}), increasing the ratio *a*/*b*. According to Evans (1989), this behavior indicates greater amounts of reaction centers in the photosystem II and lower capacity in the capture of solar energy incident, through the protein complex II of light gathering (LHCII). Similar results were obtained by Cruz et al. (2007) on photosynthetic rate on papaya as influenced by N. On the other hand, at higher levels of N the chlorophyll *b* content (3.69 mg dm^{-2}) was greater than chlorophyll *a* (3.13 mg dm^{-2}), decreasing the ratio *a/b*. This increases photochemical capacity, assuming higher electron transport speed (Evans, 1989). Chlorophyll *b* plays an important role in increasing the spectrum of light that can be used in the photosynthetical process (Raven et al., 2001).

In banana tree by presenting self-shading characteristic of its leaves, a greater relative proportion of chlorophyll *b* is an important factor as it enables the capture of energy from other wavelengths and its transfer to the specific molecule of chlorophyll *a*, which then transforms it into chemical energy in photosynthesis.

Increasing N doses enhanced the total chlorophyll, reaching a value of 6.69 mg dm^{-2} at 478 kg N ha^{-1} (R^2=0.99**) (Figure 1C), greater than 5.23 mg dm^{-2} found in the 'Grand Naine' banana trees by Thomas and Turner (2001). A higher concentration of chlorophyll in the middle of the foliar surface maximizes CO_2 assimilation. There was an increase of 77.92% in chlorophyll content from 0 to 478 kg N ha^{-1}. The relationship between the N applied and the chlorophyll content (Figure 1C) can provide a prediction of the amount of N necessary to increase total chlorophyll, as it has already done in other crops (Guimarães et al., 1999; Torres Netto et al., 2002).

Concentration of N leaf

The relationship between N leaf content and chlorophyll concentration (r=0.88**) (Figure 1D), provides additional information in predicting the amount of chlorophyll in banana tree leaf, from N leaf data. This is important, because 50 to 70% of N in the leaves is component of enzymes that are associated to chloroplasts (Evans, 1989). The relationship between the N applied through irrigation water and leaf N was significant (R^2=0.96**) (Figure 2A). Based on the equation shown on Figure 1, it was found that the N dose which maximize N leaf was

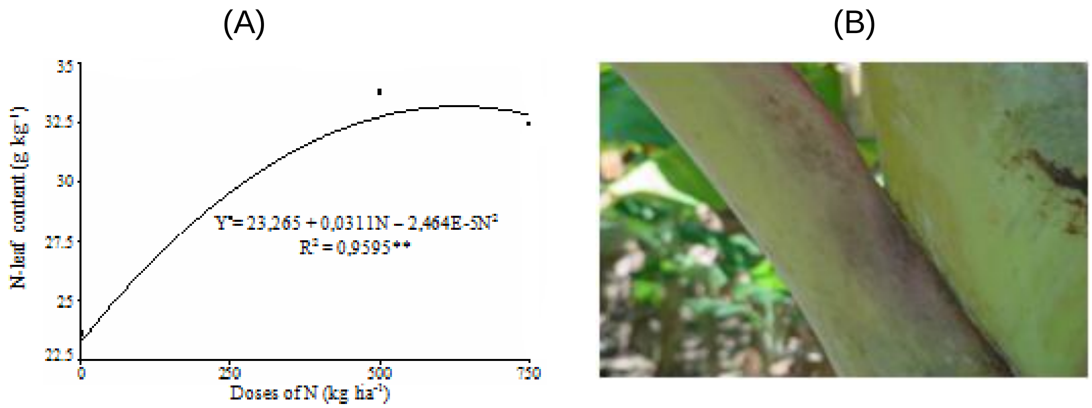

Figure 2. Effects of nitrogen applied through irrigation water on N-leaf content (A) and N deficiency symptom, showing antocianin accumulation at petiole margins (B) in banana tree cv. 'Prata-Anã'.

632.39 kg ha^{-1}. At this dose, the leaf N concentration was 33.11g kg^{-1} at the flowering stage, and was higher than the sufficiency range (25 to 29 g kg^{-1}) proposed by Silva et al. (2002). The leaf N was also higher than 30 g kg^{-1}, found by Damatto Junior et al. (2006), and between the range (27 to 36 g kg^{-1}) found by Malavolta et al. (1997). In the absence of N, the leaf N content was 23.26g kg^{-1}, which is below from the critical level proposed by Gallo et al. (1972); Martin-Prével (1984); Moreira (1999); Silva et al. (2002); Teixeira et al. (2002); Borges and Caldas (2004). In banana trees lacking nitrogen, besides plant growth decreasing, a pink color was observed at petiole margins due to antocianin accumulation (Figure 2B). Carbohydrates not used in N metabolism can be utilized for antocianins biosynthesis. The accumulation of this pigment is also an indication of nitrogen deficiency (Marschner, 1995; Taiz and Zeiger, 2009).

Concentration of K leaf

Potassium leaf content was influenced ($p<0.01$) by potassium applied through irrigation water (Figure 3A). Making the second derivative of the equation equal to zero, the K dose that maximizes K leaf is 700 kg ha^{-1}, associated to 22.13 g kg^{-1} of potassium leaf content at the flowering stage, which it is lower than the sufficiency level of 27 g kg^{-1} along with Silva et al. (2002). According to Teixeira et al. (2002), 90% of the maximum yield was achieved with 23.2 g K kg^{-1} in the leaf of banana tree 'Nanicão'. Gomes (2004) did not find any response to K fertilization applied through irrigation water on banana tree 'Prata-Anã' leaf K content. Similar results were obtained by Guerra et al. (2004). In his work the author noticed that K leaf was lower than 32 g kg^{-1} (Prezotti, 1992) without influencing the fruit yield. According to Marschner (1995), between 20 and 50 g K kg^{-1} of dry matter are sufficient for plant growth.

Increasing applied N in the absence of K decreased leaf K by 23.78% (Figure 3B). Similar results were obtained by Teixeira et al. (2002) and Silva et al. (2002). However, it was higher than 16.77% observed by Teixeira et al. (2002) at 800 kg N ha^{-1}. The decrease in leaf K can be explained by K remobilization by sugar translocation from old leaves to young organs, or due to less K absorption caused by high concentration of NH_4^+ in the soil (Marschner, 1995; Epstein and Bloom, 2006). Potassium deficiency symptom came up due to low leaf K (Figure 3C). Nitrogen soluble compounds such ammines, amides and putrescines accumulate in the apoplast and in the leaf surface, causing necrotic spots on the leaf margins, and making the plant susceptible to fungal diseases (Marschner, 1995). The symptom was higher severity at flower emission. Afterwards, leaves became old more quickly. Thereafter, the leaves entered into early senescence (Figure 3D).

Concentration of P, Ca and Mg leaf

Leaf P increased from 1.5 to 1.7 g kg^{-1} (R^2=0.9987**) (Figure 4A) as influenced by N applied through irrigation water. These values are very close to the ones found by Silva and Rodrigues (2001) and Silva et al. (2002). 16.60% of this increase may be due to an increase in root growth; that, probably, could have been an effect on phosphorus absorption. The root growth has a positive correlation with leaf area expansion, plant height and false stem circumference. By their relationship with N, P is fixed by organic compounds and used together with N in protein synthesis and in activation of enzymes needed for dry matter yield (Marschner, 1995; Taiz and Zeiger, 2009).

Leaf calcium increased with applied N (Figure 4B). The amount of N that maximized leaf calcium (7.8 g Ca kg^{-1}) was 750 kg N ha^{-1}. Increasing calcium leaf content by N

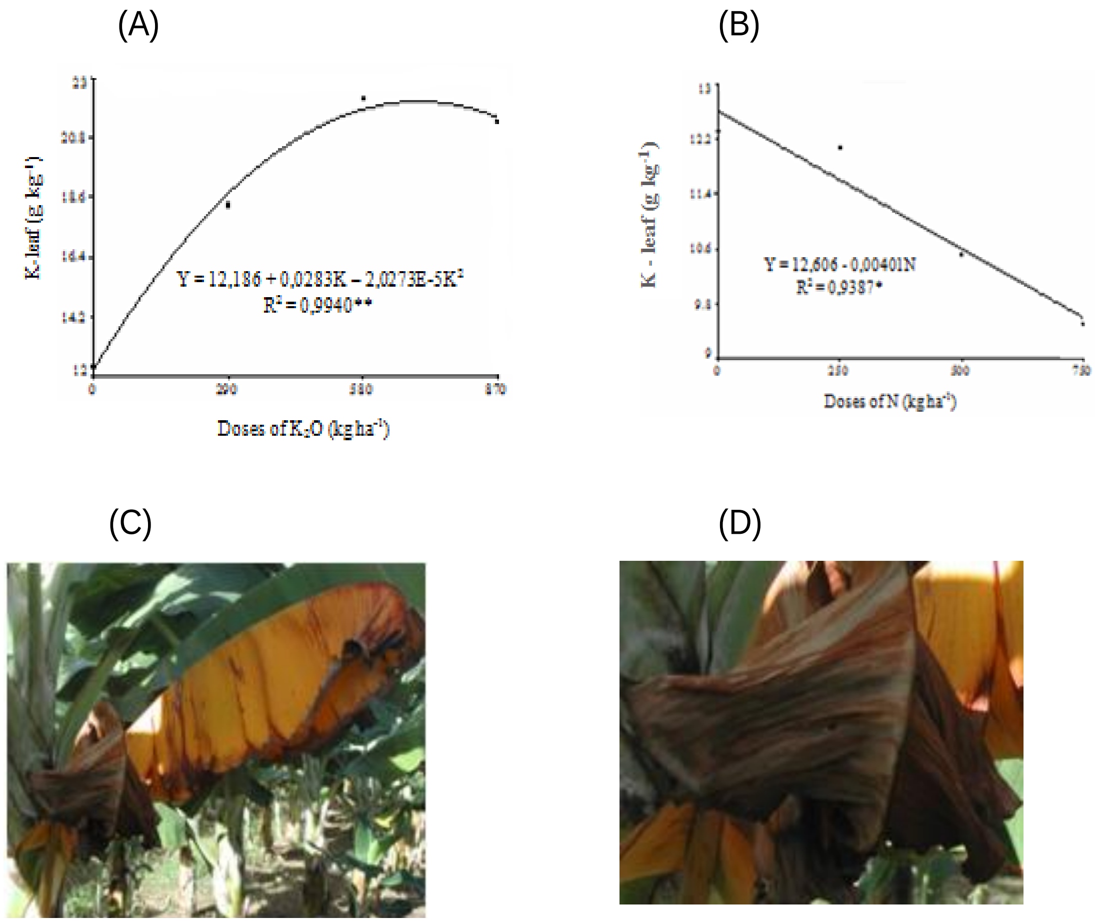

Figure 3. Effects of K (A) and N (B) on leaf and K deficiency symptoms observed in plots without K (C and D) in banana tree cv. 'Prata-Anã'.

application also was observed by Silva et al. (2002) in banana tree 'Prata-Anã'. According to the model found by those authors, 6.32 g of Ca kg^{-1} was reached with application of 750 kg N ha^{-1}. High calcium uptake was observed in plants that received N in comparison to those that did not receive N. Leaf calcium in plants that received N was 85.71% greater than in the ones that did not receive nitrogen.

Increasing K application decreased leaf calcium from 4.2 to 3.3 g kg^{-1} (Figure 4C). Though diminished by potassium application, calcium leaf content was still in the sufficiency range (2.5 a 12 g kg^{-1}) cited by Prezotti (1992); it was lower than the range of 4.5 to 7.5 g kg^{-1} according to Silva et al. (2002) and almost close to 4.1 g kg^{-1} found by Silva and Carvalho (2004). Leaf magnesium was reduced by N application from 7.3 to 5.8 g kg^{-1} (Figure 4D). The decrease in leaf Mg could be related to a greater conversion of the ammonium absorbed by amino acids avoiding magnesium fitotoxicity (Epstein and Bloom, 2006).

These authors mention that the primary pathway for this conversion involves the sequential action of glutamine synthetase and glutamate synthase. This process requires ATP hydrolysis involving a divalent cation such as Mg^{2+}. Furthermore, the increasing availability of K in soil increased the competitive effect on the absorption of magnesium, so that the amount of Mg in leaf varied from 7.2 to 6.3 g kg^{-1} when 870 kg ha^{-1} of K_2O were applied (Figure 4E). This confirms the antagonism related to the ionic balance in the absorption of Mg and K (Figure 4F), but there were no symptoms of blue-banana caused by the imbalance between K and Mg (Borges et al., 1999). It is necessary to point out that K contributes with 70.7% and Mg with 19.2% of the sum involving K+Mg+Ca found in banana tree leaves. The relative value of K is higher than 61% found by Borges et al. (1999) and the relative value of Mg is between 18 to 20%, as proposed by those authors.

Conclusions

Increasing N applied through irrigation enhances the contents of nitrogen until dose of 631.08 kg ha^{-1} of N,

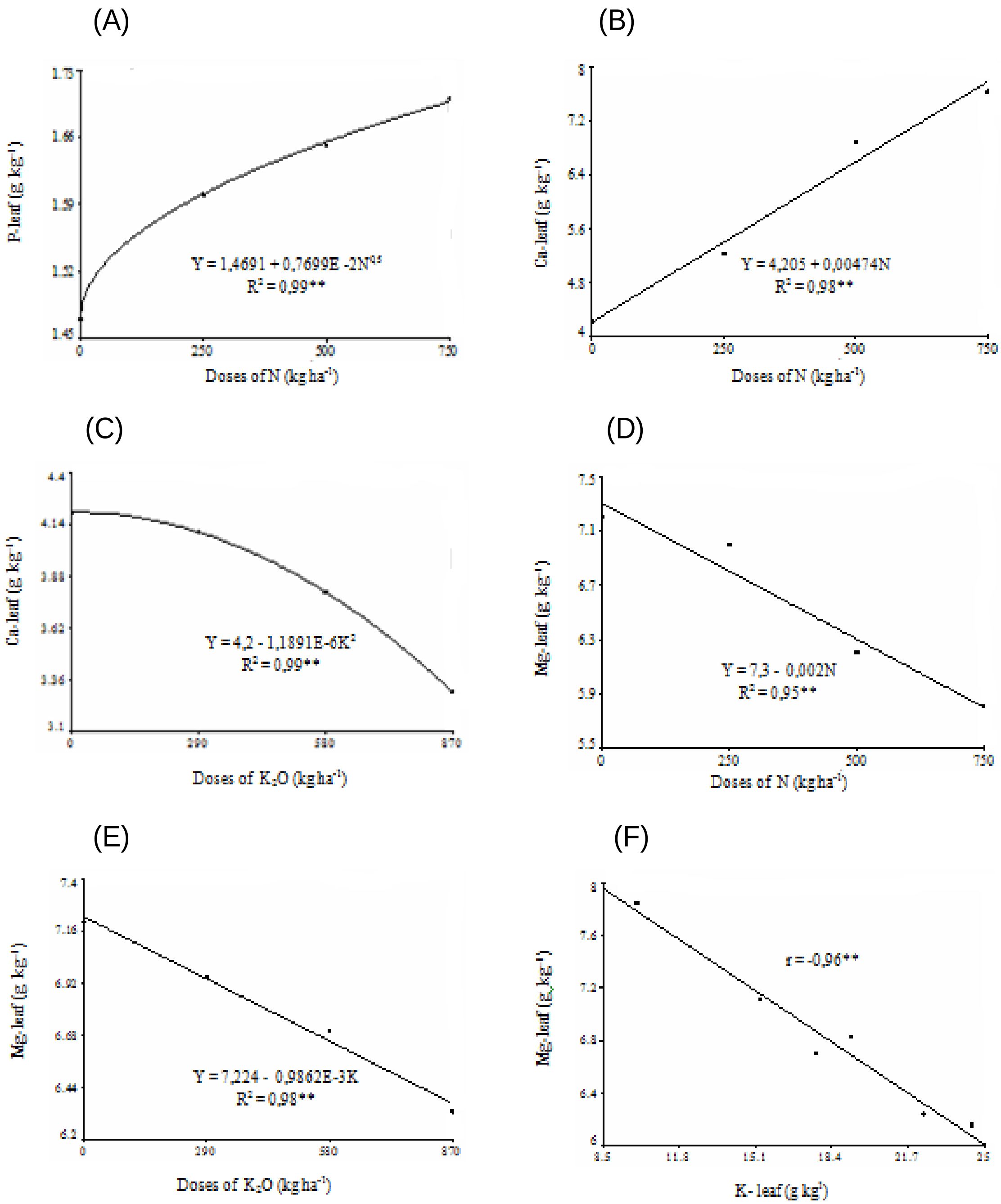

Figure 4. Effects of N on leaf P (A), Ca (B) and Mg (D) contents; effects of K on leaf Ca (C) and Mg (E) contents, and correlation between the content of Mg and K in banana tree leaf (F) cv. 'Prata-Anã'.

while chlorophyll total remains constant after 250 kg ha^{-1}. Phosphorus and calcium are increased due to high doses of N, however the contents of magnesium and potassium in the leaves of banana 'Prata-Anã' are reduced. Reference values for nitrogen, phosphorus, potassium calcium and magnesium were obtained. Increasing K applied through irrigation water increases leaf content of K until estimated dose of 698.07 kg ha^{-1} and reduces leaf contents of calcium and magnesium of banana tree.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

Choice of alternative crop enterprises among smallholder tobacco farmers in Teso District, Kenya: A multinomial logit analysis

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The study analysed the factors affecting the choice of alternative crop enterprises among smallholder tobacco farmers in Teso district, Kenya, using Multinomial logit model. Data used for the study were obtained from primary sources through structured questionnaires using a multistage sampling technique from 150 farmers selected randomly. The results indicate that farmers are indeed reducing the acreage under tobacco and venturing into other alternative crops. This shift and the choice of the alternative gone into was found to be influenced positively by factors such as land size, experience, access to extension services and distance to market. Total asset value however negatively influenced the shift to other crops. However demographic factors such as age, education, household size and gender had no role in influencing the farmers' decision to shift to alternative crops. There is therefore need for more awareness on the hazards of tobacco cultivation and facilitation to other alternative crops through support of extension services, credit, market and identification of alternatives suitable to the area for the farmers.

Key words: Multinomial logit regression, World Health Organization Framework Convention on Tobacco Control (WHO FCTC), tobacco, alternative enterprise.

INTRODUCTION

Tobacco is a widely grown non-food cash crop in the world and is cultivated in more than 120 countries owing to its ability to grow in a wide range of climatic and soil conditions (Chavez et al., 2010). In Kenya, it is grown in three regions namely South Nyanza (Migori, Kuria and Homa Bay districts), Western (Bungoma, Bumula, Malakisi, Sirisia, Busia, Teso and Mount Elgon districts) and Eastern (Meru, Embu and Kirinyaga districts) mainly under contract farming. Tobacco is a controversial crop not only because of negative impact on health from smoking but also due to its environmental issues; soil degradation, deforestation and water pollution (Ochola and Kosura, 2007; Geist et al., 2009), and social issues such as low returns/income, women and child labour (WHO, 2008; Kibwage et al., 2009).

Agriculture is the key source of food and employment for population in Teso District. Tobacco is the principal cash crop (GoK, 2008) and it is solely the only short season cash crop apart from tradable food crops like maize that dictate the economic position of full time

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small-scale farmers in the district (Ekisa, 2010). Lagat et al. (2006) found that tobacco was the most cultivated crop as indicated through the share of all cultivated land with Teso district. This could be the reason for the high food poverty incidences in the district at 49.4% (GoK, 2008), making the area food insecure.

There is a worldwide effort against tobacco growing and consumption. The World Health Organisation Framework Convention on Tobacco Control (WHO FCTC) aims at reducing tobacco production and ultimately reducing the consumption (WHO, 2005). The WHO FCTC was developed in response to the globalization of the tobacco epidemic and Article 17[1] requires signatories to provide support for economically viable alternative activities to tobacco farming. Farmers who depend on tobacco production for their livelihood will therefore need to find other alternative crops to produce. Despite the negative economic, social and environmental impacts associated with tobacco production (Ochola and Kosura, 2007; Patel et al., 2007; WHO, 2008; Geist et al., 2009; Kibwage et al., 2009), evidence suggests that land under tobacco has rapidly grown with new areas like the Rift Valley adopting the crop (Kibwage et al., 2009). This rapid growth is at the expense of food crops whose role is vital to food security and in essence undermines WHO FCTC efforts. Most research carried out in tobacco growing regions reveal that switching from tobacco to other enterprises is profitable. Research has shown that there are abundant opportunities to shift from tobacco farming to other crops (Ochola and Kosura, 2007; Patel et al., 2007; Kibwage et al., 2009; Magati et al., 2012).

Since ratifying the WHO FCTC, Kenya has supported the current global lobby on the reduction of production and consumption of tobacco through national legislation. The legislation intends, in part, to reduce tobacco production and consequently cigarette manufacture and consumption. The response by farmers who depend on tobacco production for their livelihood would be reflected by switching to alternative farm enterprises. However, it has not been evaluated whether the passage of legislation has trickled down to the extent that changes have occurred in the farm enterprise mix. Therefore, this study was done to determine the alternative enterprises replacing tobacco among smallholder farmers along with the factors influencing their choice in Teso District.

MATERIALS AND METHODS

Description of study area

This study was done in Teso district, Busia country in Western Kenya between June and July 2013. The district covers a total area of approximately 559 km^2 with a population of 338,833 and population density average of 385 per km^2. The altitude ranges from 1000 to 1500 m above sea level with mean minimum and maximum temperatures of 15 and 30°C, respectively. The district experiences bi-modal rainfall with mean annual rainfall of 1000 to 1500 mm. Agriculture is the main source of livelihood with border trade and *bodaboda*[2] trade also accounting for livelihood sustenance. Land in most parts is suitable for crop production and major crops produced include cassava, maize, sorghum, finger millet, maize, groundnuts among others whilst sugarcane and tobacco are the dominant cash crops.

Data and sampling technique

A random sample of 150 tobacco farmers in the study area was selected, using multi-stage sampling procedure. The district was purposively selected as it is the poorest, especially food poverty, in the region and environmental degradation due to tobacco cultivation has been experienced. Amukura and Chakol divisions were selected as the tobacco grown in the area requires a lot of wood fuel for curing raising environmental concerns on deforestation. Simple random sampling was then used to select 14 sub-locations and systematic random sampling was used to select a sample of 150 farmers from a list obtained from British American Tobacco-Kenya-BAT(K) and Mastermind Tobacco Kenya-MTK. Data collection involved individual personal interviews with selected farmers using a standard structured questionnaire since most of the farmers had low educational status. Notable data collected included farm specific characteristics including socio-economic characteristics of the selected farmers, size of land acquisition, distance of farm to market, crops cultivated, production, credit, extension, inputs and output and many other data relevant to the scope of study. Stata version 12 was used to estimate the model.

Analytical technique

Theoretical framework

Economic choice theory suggests that individuals are rational, and if faced with the decision to choose between two or more alternatives, will prefer the option that provides the maximum level of utility. Therefore, tobacco farmers are expected, given a choice of alternative crop enterprises, including tobacco in the initial, to make a decision as to which enterprise to engage into so that they maximise their utility. Therefore, the choice of a crop alternative that a tobacco farmer chooses is a utility maximisation problem. However, with the campaigns and education targeted at the farmers for them to reduce tobacco production, it is expected that the farmers would have understood the negative effects and known that the utility from tobacco is less compared to other crops. The messages that enlighten them on the health, environmental and social ills of tobacco if received as measure by the awareness of the farmers, are expected to help them in making a decision. Producers' uncertainty about future income from tobacco may induce them to look for alternative crop/livestock enterprises to replace tobacco.

So generally, against this backdrop, the choice or the adoption of a given coping mechanism or moving away from tobacco by households can be considered a function of the expected utility derived from using that enterprise. The utility function (Allison and Christakis, 1994; Layton, 2000) can be stated as:

$$U_{ij}=V_{ij}+\varepsilon_{ij} \quad for\ j \epsilon J_i \tag{1}$$

where U_{ij} is household *i*' is utility for adopting a given alternative

[1]The WHO FCTC treaty has different tobacco demand and supply reduction strategies contained in different articles. Article 17 specifies the provision of support for economically viable alternative activities.

[2] A motorcycle or bicycle taxi common in Western Kenya

enterprise *'j'*, V_{ij} is the deterministic component of utility for household *i* associated with adopting the alternative enterprise, and ε_{ij} is the error term associated with choosing the alternative (Train, 2003). It captures the factors that affect utility but cannot be observed, e.g. moods and other hidden perspectives.

Nevertheless, before thinking of the alternatives, the tobacco farmer must consider the options and tobacco. The potential of alternatives to replace tobacco can be evaluated by the utility the farmer get from tobacco (U_{iT}) and the utility from the alternatives (U_{ij}), and they can only replace tobacco. The difference between the two utilities (ϑ_j) can be represented as:

$$U_{ij} > U_{iT} \, or \, \vartheta_j = U_{ij} - U_{iT} \tag{2}$$

Farmers are faced with several potential alternatives to replace tobacco with several factors that will influence this decision. Generally, they include the attributes of the alternative and the farmer characteristics. The economic aspects like size of the farm, access to credit and other inputs are also going to influence this decision. The institutional factors, since tobacco is a crop with ready market under contract farming, are also going to affect the decision as the farmer compares the utility from tobacco and other crops.

Multinomial logit model

A multinomial logit model, based on the above theoretical framework was used to analyse what affects tobacco farmers' choice of alternative enterprises. Let *A* be a random variable representing the alternative enterprise chosen by any farming household *i*. We assume that each farmer faces a set of discrete, mutually exclusive choices of alternative enterprises. These enterprises are assumed to depend on a number of climate attributes, socioeconomic characteristics and other factors *x*. The probability of choosing alternative A_i among the J number of alternative enterprises and the set of explanatory variables x (Greene, 2012) was presented as:

$$\text{Prob}\,(A_i = j) = \frac{e^{\beta_j' x_i}}{\sum_{k=0}^{j} e^{\beta_k' x_i}}, \; j = 0, 1 \ldots J \tag{3}$$

Where j is the alternatives that range from none to J and β is a vector of coefficients on each of the independent variables x. k is the number of categories into which the responds may fall. Equation (3) above can be normalized to remove indeterminacy in the model by assuming that β = 0 and the probabilities can be estimated as:

$$\text{Prob}\,(A_i = j | x_i) = \frac{e^{\beta_j' x_i}}{1 + \sum_{k=0}^{j} e^{\beta_k' x_i}}, \; j = 0, 2 \ldots J, B_0 = 0 \tag{4}$$

and according to Hassan and Nhemacena (2008), Equation (4) can yield the alternative enterprises (J) J-log odds ratio as:

$$\ln\left(\frac{P_{ij}}{P_{ik}}\right) = x'\left(\beta_j - \beta_k\right) = x'\beta_j, \text{ if } k = 0 \tag{5}$$

The dependent variable is therefore the log of one alternative enterprise relative to the base enterprise. However, interpreting the coefficients can be misleading, and instead we get the marginal effects or quasi-elasticities, which indicate the percentage point change in p upon a 1% increase in x. Over all states, the probabilities sum to 1, and the derivatives and quasi-elasticities to 0. Like the derivatives, quasi-elasticities are invariant to the choice of the reference state, and they may change in sign and size when they are evaluated at different points (Cramer, 2003).

The elasticities are computed as:

$$\delta_j = \frac{\partial P_j}{\partial x_i} = P_j \left[\beta_j - \sum_{k=0}^{J} P_k \beta_k\right] = P_j(\beta_j - \bar{\beta}) \tag{6}$$

Where δ_j is the elasticity associated with alternative j, that is the change from the base enterprise to enterprise j, it is simply the coefficient associated with enterprise j minus the average of the coefficient, multiplied by the probability associated with enterprise j.

It was hypothesised that the tobacco farmers who have reduced the area under tobacco cultivation have diversified into other enterprises, which were listed according to the share of total cultivated area they occupy, and the crop enterprise occupying the largest share of area used as the alternative enterprise chosen by the farmer/household.

The log-likelihood can be derived by defining, for each individual, $d_{ij} = 1$ if alternative j is chosen by individual i, and 0 if not, for the J + 1 possible outcomes. Then, for each i, one and only one of the d_{ij}'s is 1. The log-likelihood is a generalization of that for the binomial probit or logit model (Greene, 2012):

$$\ln L = \sum_{i=1}^{n} \sum_{j=0}^{J} d_{ij} \ln \text{Prob}\,(Y_i = j | x_i) \tag{7}$$

and the derivatives take the simple form as:

$$\frac{\partial \ln L}{\partial x_j} = \sum_{i=1}^{n} \left(d_{ij} - P_{ij}\right) x_i \text{ for } j = 1, \ldots, J \tag{8}$$

n being sample size. Two models were estimated using multinomial logit. In the first model, we estimate the factors influencing the choice of an alternative including tobacco in the choice set. The idea is to determine the probabilities associated with choosing other alternatives away from tobacco. In the second model, we drop the farmers who have continued to grow or expanded the area under tobacco and only use a sub-sample of those who have abandoned tobacco. In this way, we have removed tobacco from the choice set and we are able to determine what affects the choice of an enterprise to replace tobacco after the decision to stop growing tobacco has been made.

Empirical model

The variables and empirical model was specified as:

$$\text{choice} = \beta_0 + \beta_1 \text{age} + \beta_2 \text{gender} + \beta_3 \text{hsize} + \beta_4 \text{fsize} + \beta_5 \text{totalassetval} + \beta_6 \text{exprience} + \beta_7 \text{distmkt} + \beta_8 \text{accextn} \tag{9}$$

Getting from the theoretical framework and literature, several factors are attributed to influence the choice a farmer makes as to what enterprises to engage in. The age and gender of the farmer influences choice of enterprise in that younger farmers are perceived to be liberal in experimenting and venturing into the possible alternatives facing them while older farmers are conservative. Age is also linked to experience (years engaging in a certain enterprise), that is, the older a farmer is the more experienced. The farm size (acres) also influences choice as the bigger the farm the more varied the choices facing a farmer and the same applies to household size especially in provision of labour. Distance to the market, access to extension services and total asset value especially in agricultural assets such as land, hoes, ox-ploughs, sprayer pumps and wheelbarrows; also contribute to the choice of enterprise a farmer engages in.

Table 1. Socio-economic characteristics of the farmers (Continuous).

Variable		Mean	t-value	p- value	Std Dev	Min	Max
Age	Reducers	44.7	-0.67	0.50	13.13	21	85
	Non-reducers	42.97			13.48	20	70
Household size	Reducers	5.59	0.13	0.90	1.45	1	9
	Non-reducers	5.63			2.14	1	10
Experience (Years)	Reducers	4.77	0.60	0.55	4.31	1	33
	Non-reducers	5.33			5.63	1	26
Land size	Reducers	2.77	0.89	0.37	1.94	0.5	10
	Non-reducers	2.88			1.65	0.5	7

Table 1. Socio-economic characteristics of the farmers (Discrete).

Characteristic	Reducers N=120		Non-reducers N=30		χ^2-value	Total 150	
	No.	Percent	No.	Percent		No.	Percent
Gender							
Male	116	96.67	30	100		146	97.33
Female	4	3.33	0	0	1.03	4	2.69
Division							
Amukura	60	50	20	66.67		80	53.33
Chakol	60	50	10	33.33	2.68	70	46.67
Education							
None	13	10.83	5	16.67		18	12
Primary	92	76.67	22	73.33		114	76
Secondary	14	11.67	3	10		17	11.33
Tertiary	1	0.83	0	0	1.03	1	0.67

RESULTS AND DISCUSSION

Socio-economic characteristics of the farmers

Since there were two groups, those who reduced or abandoned tobacco production to other alternative enterprises (reducers) and those who did not (non-reducers) a comparison of means was done in Table 1 using the student t-test for continuous variables at 5% confidence level.

The mean age of the reducers was approximately 45 years and that for the non-reducers was 43 years while the years of experience for both categories was 5 years with the least experience being 1 year since tobacco is an annual crop and farmers contracted may not renew the contract for the subsequent year. The average household size was approximately 6 persons whereas the average land size was approximately 3 acres indicating that majority of farmers are smallholder farmers with less than 5 acres of land. In some studies, large households and large farm sizes have been found to influence positively the uptake of more alternative agricultural practices through provision of factors of production (Ashenafi, 2007; Kibet et al., 2011).

In terms of gender (Table 2), male headed households were the majority with 97% while female headed households were only 3%. This difference can be attributed to the fact that women in the area, like in most of the Kenyan communities have neither rights to own agricultural production resources (especially land) nor power to make major decisions regarding agricultural production. The findings concur with that of

Table 3. Factors affecting enterprise chosen instead of tobacco.

Variables	Marginal effects (ME)				
	Maize	**Cassava**	**Millet and sorghum**	**Vegetables**	**Rice and sugarcane**
Log of total asset value	0.000**(0.000)	0.000*(0.000)	-0.000**(0.000)	0.000(0.000)	-0.000(0.000)
Household size	0.011(0.037)	-0.009(0.027)	-0.012(0.025)	-0.010(0.027)	0.011(0.027)
Distance to market for the alternative crop enterprise	0.009(0.010)	-0.015(0.012)	0.006**(0.003)	-0.010(0.010)	0.008***(0.003)
Access to extension services	-0.214(18.065)	0.061(3.551)	0.116(5.591)	0.184(2.366)	0.229(3.807)
Tobacco farming experience	0.013(0.015)	-0.016(0.016)	0.019**(0.007)	0.003(0.007)	-0.021(0.018)
Gender of household head	-0.144(0.341)	0.003(0.155)	0.038(0.222)	0.013(0.184)	0.062(0.526)
Age	-0.039(0.038)	0.030(0.024)	0.032(0.026)	0.031(0.024)	-0.050(0.031)
Land size	-0.143*(0.079)	-0.060(0.044)	0.249***(0.093)	-0.067(0.047)	0.045(0.062)
LR Chi (45) = 74.32					
P-value = 0.0039					

Standard errors in parentheses. *** ** * indicate significance at 99, 95 and 90% confidence level.

Kibet et al. (2011). The high labour requirement in tobacco production was also evidenced by the lack of any female among the non-reducers given that most female headed households were widowed.

The bulk of farmers having only attained primary or no education at all indicate the low levels of literacy in the district (Lagat et al., 2006; GoK, 2008) and also the inability of parents to take their children to secondary school which could be due to high poverty incidences of 59.5% according to GoK (2008). Education levels are said to influence choice to modern methods of production that need advanced skills unlike low levels of education which may leave the farmer with no choice than to practice traditional forms of production. The Chi square results revealed that there were no differences among the reducers and non-reducers in relation to gender, division and education level. This can be because of the homogeneity of the population which can be attributed to the fact that the farmers share same systems of production and are exposed to similar environment such as weather and institutional factors.

Econometric results

Table 3 shows the marginal effects results of the model. The reference for the model was the farmers who have not reduced tobacco production in the reference years. The model fits the data well as indicated by the Log-likelihood Ratio (LR) which is significant at $\alpha = 0.01$. This means that the model has strong explanatory power and variables included are jointly significant. The pseudo R-squared is also good though it may not be a very good measure of fit in multinomial cases (Greene, 2012).

Household size, age and gender of the household head, were not significant in determining what enterprise a farmer goes into. The sign of these coefficients are as expected and the fact that they are not significant seems to suggest that the household characteristics have little effect on the farmers' decision on the choice of enterprise (Kalineza et al., 1999). Distance to market was also positive for growing of rice and sugarcane with a slightly higher marginal effect significant at 99% confidence level. Given the bulkiness of sugarcane in marketing, the result is quite surprising. However, bearing in mind that the selling points for raw sugarcane are well distributed throughout the area through contracted farming that provides transportation to the millers, the likelihood of growing cane being positive is plausible as distance to market increased for other crops. The longer the distance to market for what a farmer considered an alternative, the higher was the probability of them growing sorghum and millet compared to continuing with tobacco. With an increase in distance to market of say 10%, the probability of growing millet and sorghum increases by 6%. Given millet and sorghum are like the second staple (Salasya et al., 2008; Gill, 2010) and they are less bulky crops, farmers far away from the market may resort to them after abandoning tobacco.

Land size was another major of the enterprise

Table 4. Factors that influence the choice of an enterprise.

Variables	Marginal effects (ME)			
	Maize	Millet and sorghum	Vegetables	Rice and sugarcane
Log of total asset value	0.285**(0.127)	-0.102(0.113)	0.167(0.109)	-0.143(0.113)
Household size	-0.014(0.028)	-0.024(0.026)	-0.008(0.028)	0.004(0.026)
Distance to market for alternative crop enterprise	-0.015(0.012)	0.007**(0.003)	-0.009(0.010)	0.008***(0.003)
Access to extension services	-0.004(0.084)	0.010(0.068)	0.145**(0.061)	0.204***(0.058)
Experience in tobacco farming	-0.018(0.016)	0.014*(0.007)	0.006(0.007)	-0.025(0.018)
Gender of household head	0.011(0.144)	0.013(0.206)	0.035(0.176)	0.068(0.480)
Age of household head	0.021(0.023)	0.045*(0.025)	0.022(0.024)	-0.028(0.028)
Farm size (in acres)	-0.106*(0.056)	0.047(0.038)	-0.071(0.051)	0.045(0.042)
LR = 68. 37				
P-value = 0.000				

Standard errors in parentheses. *** **, * indicate significance at 99, 95 and 90% confidence level, respectively.

that a farmer went into away from tobacco. For millet and sorghum, land size had a positive relationship that is significant at 1% significance level. With increase in land size by an acre, the probability of farmers preferring to grow millet and sorghum instead of tobacco increased by about 25%. This implies that large farm may enable households to allot their land to multiple cereal crops than small holders (Rehima et al., 2013). Previous studies indicated that land size positively affected type of crop, variety or agricultural enterprise that farmers engaged (Rahman, 2008; Hassan and Nhemacena, 2008; Ojo et al., 2013). The increased probability of growing millet and sorghum as land size increases could have more to do with the cultural attachment to the crops as they are favourite for *ugali*[3] and beer brewing among the Teso community (Salasya et al., 2008; Gill, 2010).

Choice of enterprise for reducers

A second estimation was done that used only the farmers that have reduced the area under tobacco production. In this model (Table 4), the reference or base category is the cassava, which is among the most common crop in the area. It also requires less investment with generally low management levels but can still do well. In estimating this model, the factors that influence the choice of an enterprise for farmers who have decided to reduce were determined. The difference with the first estimation is mainly in the exclusion of farmers who had not reduced the area under tobacco cultivation and hence the exclusion of tobacco among the alternatives. The Marginal effects are presented in Table 4.

Total asset value influenced positively the growing of maize away from cassava. With an increase in say 10% in the total asset value, the likelihood of a farmer who has reduced growing tobacco to opt for growing maize increased by about 28.5%. The assets that were measured included among them agricultural implements like ploughs. Similar findings with regards to asset position were also observed (Dilruba and Roy, 2012). Distance to market was another variable that was significantly influencing the choice of an enterprise after the farmer decides to reduce tobacco production. Millet and sorghum and rice and sugarcane were more likely to be the crops turned to after reducing area under tobacco as the distance to market increased for the farmer. Millet and sorghum could be benefiting due to them being not so bulky while for cane, it could be due to availability of market from the contracting millers operating in the area.

Advisory services through extension are very important in encouraging adoption of new technologies and encouraging farmers to diversify into other non-traditional crops (Kibet et al., 2011; Rehima et al., 2013). Farmers who had access to extension service were more likely to go into vegetables, rice, and sugarcane. It is therefore possible that the farmers who had no access to extension service did not consider growing them as they could have lacked the technical information needed in the management of these crops. Experience in tobacco growing, measured in years, had a significant influence on the choice of an enterprise at 90% confidence level. With a one-year increase in experience in growing tobacco, the preference for millet and sorghum compared to cassava increases by about 1.4%. This could still be explained by

[3] Dish of maize flour cooked with water to a dough like consistency

the importance of the cereals in the community.

In addition, experience is linked to age and thus the older farmers preferred the traditional crops that they are conversant with. The age of the farmer was also significant in influencing the choice of an enterprise. Aged farmers tended to prefer millet and sorghum to cassava, with an additional year increasing the probability of opting for cassava by about 4.5%. Dilruba and Roy (2012) indicated that aged farmers are less risky takers and hence after abandoning tobacco, prefer the more traditional millet and sorghum compared to these other crops.

CONCLUSION AND RECOMMENDATION

This study has shown that there is no significant difference in socio-economic characteristics and institutional characteristics between those who abandon tobacco production for other alternative enterprises and those who do not. That is, $p > 0.05$ for all the factors captured. Thus, tobacco reducers had no comparative advantage of taking up alternative enterprises other than tobacco over the non-reducers in terms of incentives and drivers of shifting to other alternatives facing them. The multinomial regression analysis suggests that farmers' years of experience, land size, access to extension, distance to market are statistically significant in determining the alternatives farmers go into after abandoning/reducing acreage under tobacco. It is therefore apparent that government should enforce legislation that will help farmers overtime to completely abandon tobacco production. Hence, suitable alternative crops should be identified according to the climate and soil type of the area. Provision of extension services is also paramount in equipping farmers with needed skills and so is making credit accessible to the farmers either in monetary terms or provision of inputs. Government should also facilitate the marketing of the farmers produce.

Conflict of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

Determinants and incentives for soil conservation on farms in Central Gujarat: An empirical study

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The present study examined the effect of incentives in crop production and identified the determinants of incentives on farmers in Central Gujarat. The real domestic prices of the pearl millet, the major crop, moved in tandem with incentive component over time. But this incentive failed to provide push to the crop productivity of pearl millet during the period. The real domestic price of pearl millet declined during the period under study. The factors such as prevailing interest rate and rural road infrastructure significantly affected the total factor productivity in the crop. While easy loan facility by banks with accessibility to smallholder farmers could go a long way, access to local market could also be ensured with good connectivity of road particularly the smallholders farmers located closer to ravines.

Key words: Soil conservation, incentive, determinants.

INTRODUCTION

The extent of area under water erosion in India is 23.62 M ha (Maji et al., 2010). The urgency of a nation-wide policy for dealing with various problems relating to water erosion has been emphasized through the First Five Year Plan. During the Second Plan, a small beginning was made for the reclamation of ravines, and pilot projects were set up in Madhya Pradesh and Gujarat. Programmes for successive Five Year Plans further provided for the reclamation of ravine lands. These programmes achieved partial success and it was argued that the problem of land degradation in general and adoption of conservation practice in particular in ravine lands of Gujarat cannot be tackled in isolation and must find a place in the approach of holistic development of small and marginal farms (Pande et al., 2011; Bamire and Amujoyegbe, 2005). The small and marginal farms along the course of ravines are characterized by small holding size with multidirectional slope. These vulnerable holdings have little scope of consolidation; as a result the farming is mainly practiced as subsistence agriculture. Productivity growth on such farms could address the problem of poor profitability and low farm investment leading to a vicious circle of poverty as total factor productivity gains are closely tied to increases in retained profits (McGuckin, 1992).

Scholars have examined the issue of productivity

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growth and documented various factors directly and indirectly affecting its determinants in the context specific to the studies. At macro level, Government tax policies and investments on R&D, in addition to the regional factors, have been highlighted (Hsu et al., 2003; Thiele, 2002). Yet the regional disparities also warrant further investigations on other socio-economic and geographic characteristics of provincial agricultural production (Hsu et al., 2003). Furthermore, McMillan et al. (1987), Wen (1993), and Lin and Wen (1995) provided comprehensive reviews on the total factor productivity (TFP) growth in China's farm sector during the reform era. They contended that the rapid TFP growth partly contributed to the rural China's miracle growth in the early 1980's. In the Indian context, Chaudhary (2012) observed efficiency decline in half of the Indian states implying, thereby, huge potential for increase increase in production even with existing technology.

Using Johansen's cointegration procedure, Thiele (2002) estimated the long-run relationship between agricultural production, direct and indirect price incentives, and non-price factors, for ten selected SSA countries over the period 1965 to 1999. These studies, by and large, have drawn attention to the association of factor productivity and agrarian economic growth. Examination of factor productivity and its determinants, therefore, could reveal the policy options to enhance farm profitability on small farmer holdings. The present study is an effort to examine the farm productivity in general and incentives for adoption of soil conservation measures in particular through total factor productivity analysis of the major cropping system on smallholder farms in Mahi ravines. The factors determining farm productivity are also examined for policy implications. The conservation measures, on marginal, small and medium farms, included land leveling and earthen bund along field boundaries in the slopy land parcels done through initial state help. These farms usually had positive effect on crop production with part of net returns invested to buy better parcels of field away from ravine lands (Pande et al., 2011).

MATERIALS AND METHODS

Study area, sample size and data collection

About four hundred thousand hectares of land is under gully erosion in Gujarat, majority falling in central Gujarat region. The maximum gullied land falls in Baroda district, followed by Kheda district (Figure 1). Large portion (71.3%) of the land is in 0 to 5 t /ha/yr soil loss category (Kurothe et al., 1997). Further moderate to slight (5 to 10 t/ha/yr) erosion occurs in parts of Surat, Valsad, Bharuch, Panchmahal, Sabarkantha, Banaskantha, Kheda, Bhavnagar, Junagarh, Rajkot and Surendranagar districts in an area of 21690 km^2. Parts of the State under 10 to 15, 15 to 20 and 20 to 40 t/ha/yr classes are in Banaskantha, Kheda, Junagarh, Surendranagar, Rajkot and hilly areas of Panchmahal, Vadodara, Bharuch, Surat Valsad and the Dangs districts. This comprises 6.4% of the total geographical area. Only 0.3% of the area is subjected to very severe erosion due to high rainfall intensity and/or topography in Surendranagar (dry grassland) and Bharuch districts. Based on maximum area under ravine problem and soil erosion problem, therefore, central Gujarat was a natural choice for study. Since the largest gullied area of 61,888 ha is along the River Mahisagar (Sharma et al., 1981), the ravines of Mahisagar were selected for the study. Two districts, Vadodara and Anand were selected along the left and right bank of the Mahi River, where most of the ravine lands are spread (Figure 2). Five villages, two in Anand district and three, in Vadodara district were selected based on ravine area in the districts. A list of farms, comprising marginal, small and medium farm category, with lands adjacent to ravine lands was finalized and data on land use and crops, collected. Thus, a sample of 120 farms was selected for the analysis.

Structured questionnaire was used to collect specific information related to study from the field. Surveys were conducted during 2003 to 2004 through 2004 to 2005 to elicit primary information on soil conservation history, crop and cropping system adopted on the farms. The marginal farmers owned an average landholding of 0.6 ha, small and medium farms, an average holding size of 1.5 and 2.9 ha, respectively, among the farms with conservation history. The medium and large farms had 50% or more land under ravines; marginal and small holdings had only a small share of land under ravines. On the other hand, among the farms without conservation history, the marginal farmers owned an average landholding of 0.5 ha, while small and medium farmers had an average holding size of 1.3 and 2.8 ha, respectively. Bajra (*Pearl millet*) and Bajra-based cropping system was most prevalent across all the categories of farms. The secondary data on input and output of Pearl millet in respect of Vadodara district was collected from Government records since maximum gullied lands falls in this district. This data represented the Pearl millet production system of Mahi ravines (Appendix I).

Model used

The model used in this study captures the component of incentives in soil conservation through policy induced changes in total factor productivity and then decomposes the total factor productivity into productivity changes brought about by incentive and other residual factors.

The model formulation was done following Che et al. (2004) and McMillan et al. (1989) as under.

Let N represent total farmers and L represents total sown area. Further, let ε_n represent the level of effort of a typical farmer so that for N workers $\varepsilon_n N$ represent the effective contribution of labour to output measures in 'efficiency units'. The value of ε_n can be broadly interpreted to include everything that determines the quality of the farmer's labour as well as the willingness to internally exert more effort due to the enhanced incentives that accompany initial state assistance including market, credit, extension service if any. A typical farmer is expected to manage his land use in a way which increases the productivity of a given area. Let L represent total sown area and let ε_l capture the effort associated with land improvement. This may involve effort directed towards increasing the number of different crops or increasing the yield on a given land holding. Let $\varepsilon_l L$ represent the total input of land measures in efficiency units.

The technical constant return to scale production function[@] can be given as,

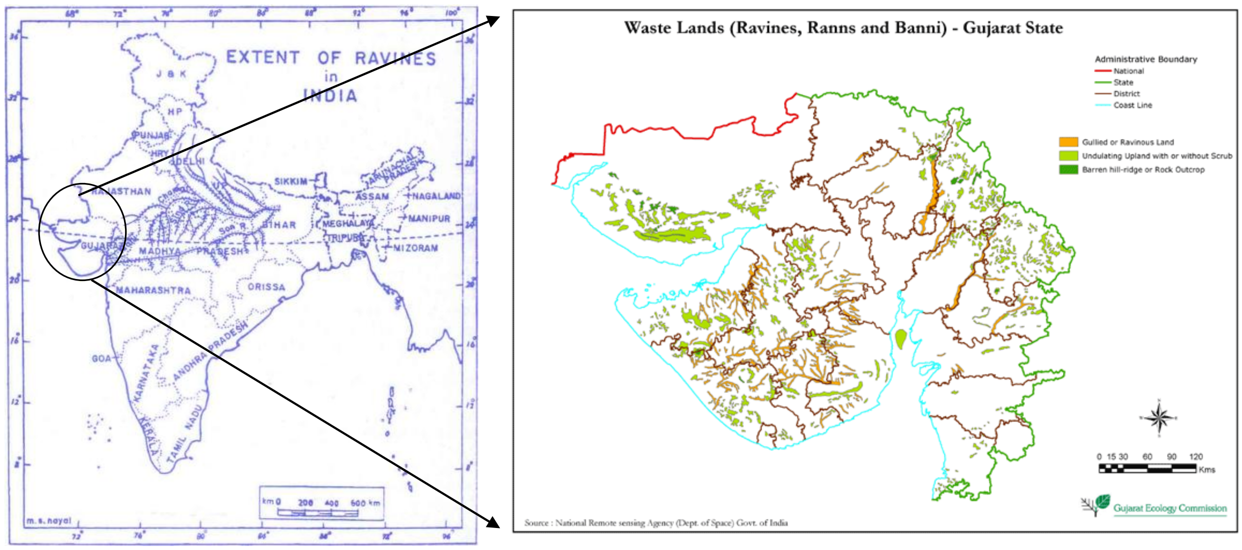

Figure 1. Gullied lands in Gujarat. Source: Dhruvanarayana (1993); Gujarat Ecology Commission.

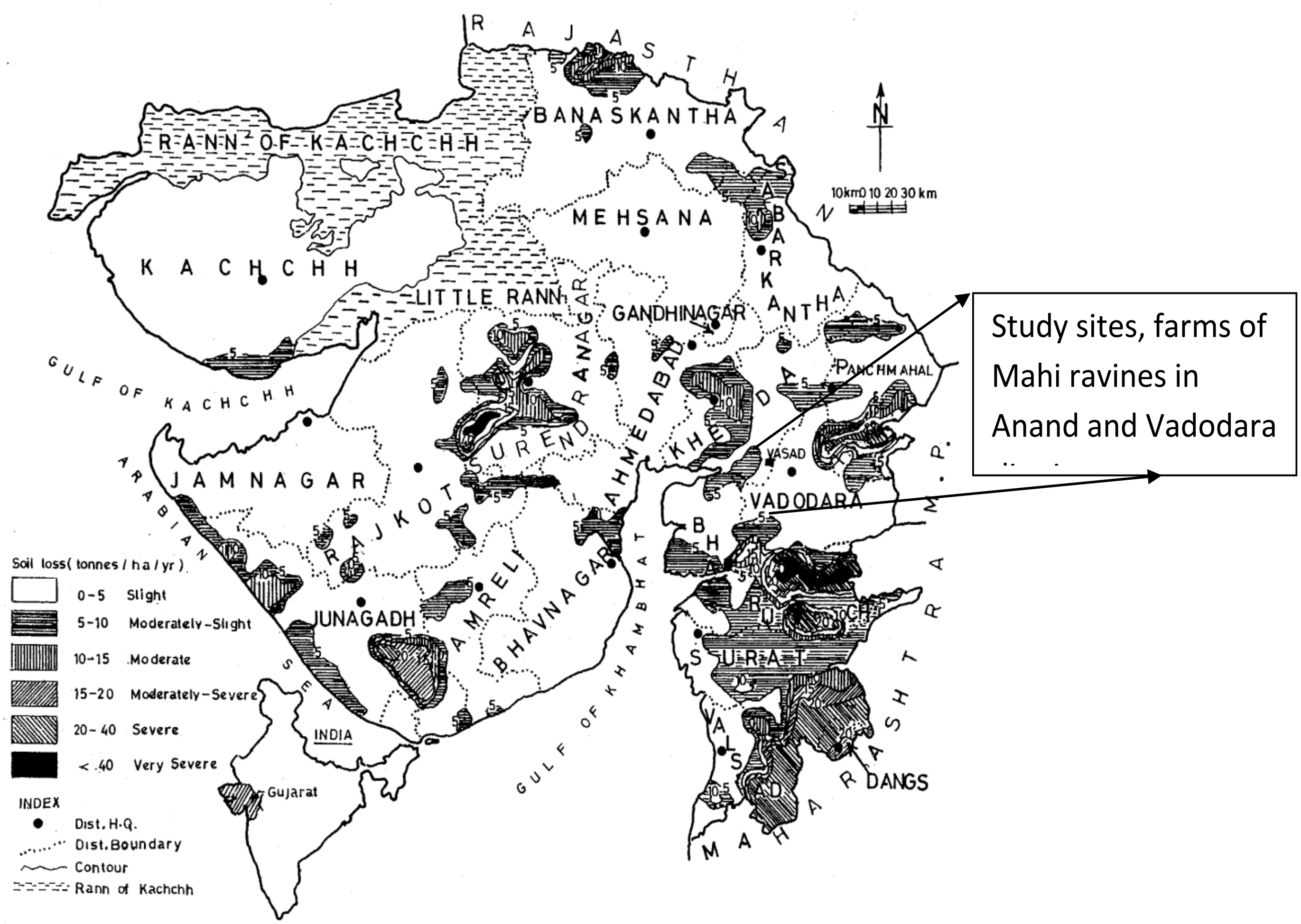

Figure 2. Soil erosion map of Gujarat. Adopted from Kurothe et al. (1997).

$$Q = \alpha_0 (\varepsilon_l L)^{\alpha_1} (\varepsilon_n N)^{\alpha_2} M^{\alpha_3} K^{\alpha_4} \tag{1}$$

Where

Q = total output

L, N, M, K = land, labour, material inputs and capital inputs, respectively

αi = Share parameters on factor inputs, i = 1,2, 3, 4

The production of a representative farmer can be given (in per capita terms) as,

$$q = \alpha_0 \varepsilon_n^{\alpha_1} (\varepsilon_l l)^{\alpha_2} m^{\alpha_3} k^{\alpha_4} = Q/N \tag{2}$$

where, q and l, m, k = output and land, material input and capital input per farmer.

Farmer's profit function

Farmer's income from agricultural production is given as,

$$y = p(q - d) \tag{3}$$

where,

p = price of agricultural output

q = output produced

d = fixed rent or lump-sum tax, the farmers pays to state.

Assuming the farmer chooses inputs in order to minimize costs, the total cost (TC) function is given by

$$TC = c_0 \sum_i x_i^{\alpha_i} Q \tag{4}$$

Where, α_i are the share parameters in the technical production, c_0 is a constant and x_i are input prices indexed across labour, land, material, inputs and capital.

Defining $X(x) = \sum_i x_i^{\alpha_i}$ as the average (real) factor price, cost of production is given as,

$$C = c_0 X(x) Q \tag{5}$$

Further, considering factor and product prices generally change at different rates, this can be captured as, $\beta = X(x)/p$ which is weighted cost share parameter or ratio of observed average factor to product prices.

Using Equations (3) and (5) and the definition of β, farmer's profit function (π), thus, becomes

$$\pi = p(q - d) - c_0 \beta(x) q$$

In other words,

$$\pi = p[q(1 - c_0 \beta) - d] \tag{6}$$

Further, in order to examine the relationship of incentive with farmer's behavior, utility function approach could be used.

Farmer's optimal behaviour and regional production function

Assuming the farmer receives utility from income but dislikes the effort of hard work and planning for more efficient use of land, including investment on farm. Following McMillan et al. (1989), his utility is given by the function,

$$U(\pi, \varepsilon_1, \varepsilon_2) = \pi - \frac{\varepsilon_n^z}{z\delta} - \frac{\varepsilon_l^z}{z\delta} \tag{7}$$

Where,

δ > 0 and z > 0 are constants, so that marginal dis-utility of effort increases with effort.

z = effort- disutility coefficient (Measures curvature of utility function) (assumed to be same across effort variable for land and labour).

z is analogous to coefficient of risk aversion and δ is taken such that the utility function is concave.

Substituting Equations (2) and (6) gives,

$$U(\pi, \varepsilon_1, \varepsilon_2) = p[\alpha_0 \varepsilon_n^{\alpha_1} \varepsilon_l^{\alpha_2} l^{\alpha_2} m^{\alpha_3} k^{\alpha_4} (1 - c_0 \beta) - d] - \frac{\varepsilon_n^z}{z\delta} - \frac{\varepsilon_l^z}{z\delta} \tag{8}$$

Farmer's optimal choice of effort levels can be obtained from this. The production function, as given in Equation (8) is maximized with respect to ε_n and ε_l. This implies that the optimal values for labour and land effort must satisfy

$$\varepsilon_n^* = (\delta p (1 - c_0 \beta) \alpha_0 l^{\alpha_2} m^{\alpha_3} k^{\alpha_4} \alpha_1^{(z-\alpha_2)/z} \alpha_2^{\alpha_2/z})^{1/\nu} \tag{9}$$

and

$$\varepsilon_l^* = (\delta p (1 - c_0 \beta) \alpha_0 l^{\alpha_2} m^{\alpha_3} k^{\alpha_4} \alpha_1^{(z-\alpha_1)/z} \alpha_2^{\alpha_1/z})^{1/\nu} \tag{10}$$

for $\nu = (z - \alpha_1 - \alpha_2)$.

Substituting Equations (9) and (10) into the per capita technical production function as given in Equation (2) and multiplying both sides by N, gives the following 'regional' production function,

$$Q = A N^{\gamma_1} L^{\gamma_2} M^{\gamma_3} K^{\gamma_4} \tag{11}$$

where the total factor productivity (TFP) coefficient A is given by

$$A = \alpha_0^{z/\nu} \delta p (1 - c_0 \beta)^{(\alpha_1 + \alpha_2)/\nu} \alpha_1^{\alpha_1/\nu} \alpha_2^{\alpha_2/\nu} \tag{12}$$

and share parameters for labour land, material inputs and capital are,

$$\gamma_1 = (z\alpha_1 - \alpha_1 - \alpha_2)/\nu \tag{13}$$

$$\gamma_2 = z\alpha_2/\nu \tag{14}$$

$$\gamma_3 = z\alpha_3/\nu \quad (15)$$

$$\gamma_4 = z\alpha_4/\nu \quad (16)$$

Equation (11) may be called 'regional' production function to distinguish it from the 'technical' production function. While technical production function reflects technical relationship between inputs and outputs, Equation (11), in addition, also incorporates farmers' response to institutional/ policy arrangements. The regional production function captures the farmer's response to non-price factors and government policies, through changes in effective prices (p), average ratio of input to product prices (γ) and (z) which reflects farmer's risk taking ability and is taken to be governed factors like credit availability and its cost to farmers, extension support etc.

Equation (12) was estimated using observable input and output data for Vadodara district in particular. Double-log regression model was used to regress total factor productivity on policy variables.

Factor productivity and incentives

Here, attempts were made to capture the component attributing to change in factor productivity and examine its effect on total factor productivity. The regional production function (Equation 12) is used to decompose TFP coefficient (A) into two components; the first component, attributable to incentive effects as captured in effort variables or

$$A_1 = [\beta p(1 - c_0\beta)]^{(\alpha_1+\alpha_2)/\nu} \quad (17)$$

and the unexplained residual

$$A_0 = \left(\delta^{\alpha_1+\alpha_2}\alpha_0^z\alpha_1^{\alpha_1}\alpha_2^{\alpha_2}\right)^{1/\nu} \quad (18)$$

Where $A_1.\ A_0 = A$ and $\nu = (z - \alpha_1 - \alpha_2)$.

The unexplained residual reflects a host of other factors. While z, δ, α_1 and α_2 are known and assumed to be time invariant, α_0 will vary over time. Further, since the time path of A can be estimated as Solow residual and we have time series data for p and β, a time path for the incentive component of TFP or A1 can be estimated. Using this framework, Total Factor Productivity (12) and incentive components (17) and (18) were computed.

RESULTS AND DISCUSSION

Gujarat occupies third place in the country in terms of area and production of pearl millet. This is the major crop in the subsistence farming of this region. Incidentally, this is also the major cropping system of smallholder farmers in Mahi ravine area. So, examination of total factor productivity of this crop would not only reveal the productivity scenario but also the reasons of subsistence on these farms. For this, regional production function of this crop was fitted using statistics of Vadodara district and this was used to compute total factor productivity indices.

Adoption behaviour of soil conservation practices

Farms in general perceived occurrence of run-off and its effect on crop production; however, the individual efforts to adopt conservation measures were meagure. In fact, the majority of marginal, small and medium farmers (more than 60%) got it done initially through the state agency. Some of the farmers, however, later made some investment on maintenance. Further, the farms with conservation history invested on the maintenance of conservation measures, though a small amount; on earthen bunds (earthen field bund and levelling were reported to be the only conservation measures).

Regional production function, total factor productivity and incentive

The Regional production function was fitted with data on pearl millet input and output for Vadodara district. The production function fitted is as under,

$Y = 1.31\ N^{0.71} L^{0.80}\ M^{0.25}\ K^{-0.30}$ $\quad n = 17, R^2 = 0.60$
(1.62)(0.40)(0.71)(0.37)(0.36)

The fitted function was reasonably good and explained sizeable proportion of variation on crop production by the variables. This was used for further computation of incentive component using Equations (17) and (18).

The total factor productivity (TFP) calculated as Solow residual is presented in Tables 1 and 2. The total factor productivity indicated sharp fluctuations during the period with a cyclical pattern (Figure 3) peaking at a time lag of four years, the highest during the year 1997 to 1998. Weather partly explained the variation (Figure 4). The crop mainly grown as rainfed responded to the rainfall; the rise in factor productivity coincided with better rainfall with time lag of one year. The total factor productivity, however, did not change during the period of study. This is line with other observations of efficiency decline in majority of the Indian states (Chaudhary, 2012). This has serious implications for the farms of the region, in general and smallholder farmers in particular. In absence of factor productivity growth, these farms have failed to generate surplus from the agriculture as farm profitability has been quite low. Most of these smallholder farms are still practicing subsistence farming. Therefore, it was pertinent to examine the price and non-price incentives giving push to factor productivity on these farms. This was examined by computing the incentive component in the total factor productivity.

The index of incentive component (Index of A1) varied from 26% in 1988-1989 to 92% in 1994-1995 during the period of study (Table 3). Further, as a proportion of total

Table 1. Index of total factor productivity (1986-1987 = 100) for Pearl millet production in Mahi ravines.

Year	Total factor productivity
1986-1987	100.00
1987-1988	68.84
1988-1989	124.97
1989-1990	133.19
1990-1991	105.38
1991-1992	93.49
1992-1993	122.26
1993-1994	134.47
1994-1995	93.41
1995-1996	121.56
1996-1997	133.69
1997-1998	161.28
1998-1999	88.80
1999-2000	98.85
2000-2001	68.43
2001-2002	68.38

Table 2. Indices of output, input and TFP growth in pearl millet, Vadodara.

Year	Total output	Land	Labour	Material input	Capital	TFP growth
1986-1987	94.6	104.5	109.1	100.2	90.1	
1987-1988	75.3	111.2	120.5	100.5	121.4	-0.31
1988-1989	123.1	115.2	131.1	101.6	96.1	0.82
1989-1990	129.6	110.7	130.7	112.1	91.0	0.07
1990-1991	105.9	108.4	131.3	123.2	101.1	-0.21
1991-1992	95.2	101.7	130.2	122.1	106.1	-0.11
1992-1993	118.3	92.7	121.3	100.9	84.5	0.31
1993-1994	128.5	92.1	120.5	112.7	71.9	0.10
1994-1995	93.0	84.8	114.4	117.5	75.8	-0.31
1995-1996	118.8	100.6	139.7	140.7	101.2	0.30
1996-1997	127.4	87.6	125.5	123.6	98.2	0.10
1997-1998	152.7	102.2	155.7	185.5	101.4	0.21
1998-1999	87.6	71.9	112.8	135.4	62.0	-0.45
1999-2000	97.3	80.3	129.3	151.2	58.9	0.11
2000-2001	69.4	63.5	104.0	93.6	53.9	-0.31
2001-2002	69.4	63.5	106.7	93.6	61.3	-0.001

factor productivity (TFP), the incentive component varied from 21% during 1988-1989 to 98% during 1994-1995 reflecting remarkable contribution towards the growth in TFP. It is interesting, however, to observe the trend of real domestic price of pearl millet during the period. This was defined as the ratio of farm harvest price for pearl millet in Vadodara district and the consumer price index for agricultural labour. The role of this price indicator as incentives to farmers is positive as the real domestic price, which indicates purchasing power of a unit of farm produce, have moved in a similar trend as that of incentive component over time (Figure 1). This implies that the price indicator provided positive signal to farmers to continue with existing production system. However, as seen from the data (Figure 1), the real domestic prices of pearl millet, in fact, declined during this period. It can be argued that the observed fluctuations of TFP in Mahi ravines are partly explained by change in real domestic price of Pearl millet realized by the smallholder farmers. However, this incentive failed to provide push to the crop productivity of pearl millet during the period. Further, since change in total factor productivity (TFP) results

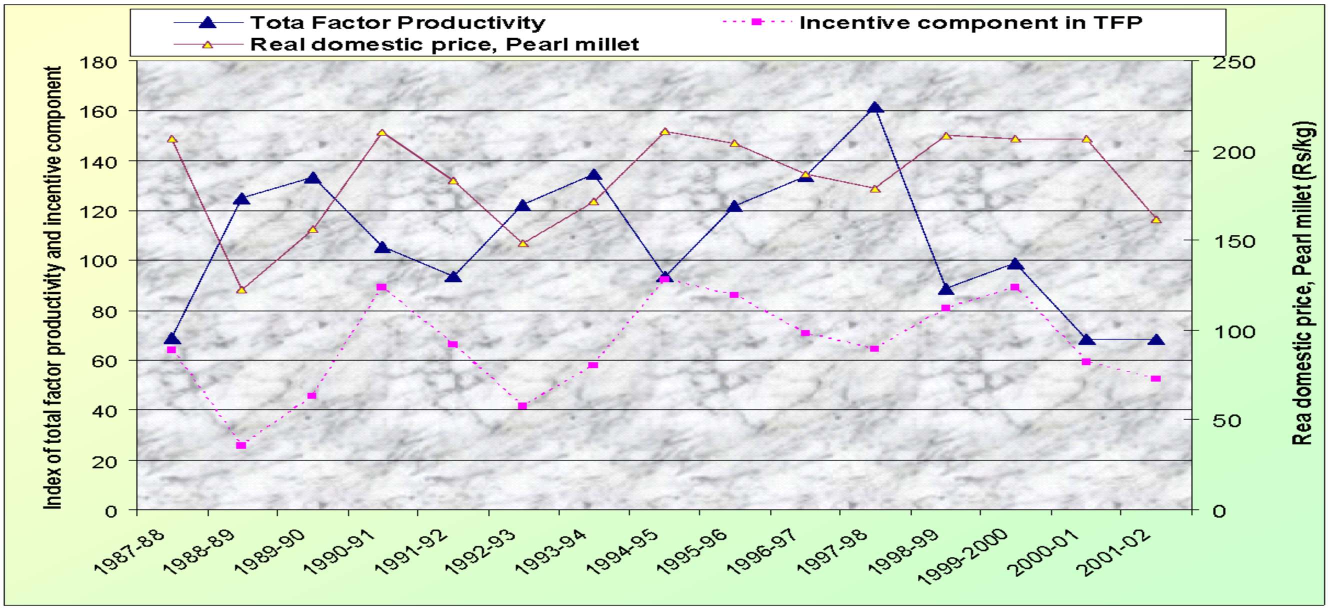

Figure 3. Indices of total factor productivity and real domestic price in Pearl millet production, Mahi ravines.

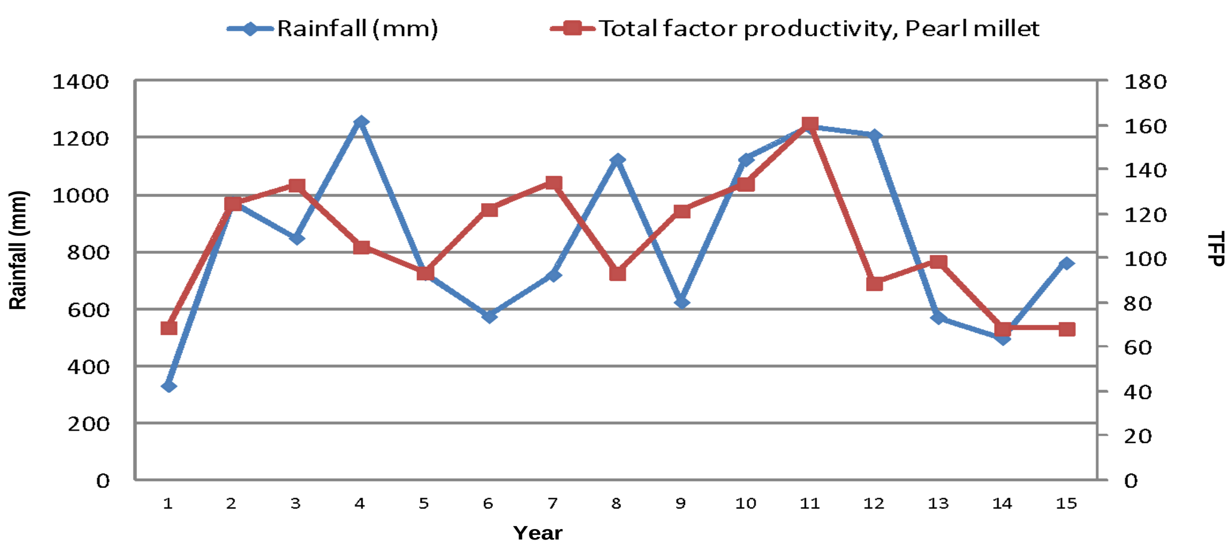

Figure 4. Total factor productivity indices (Pearl millet) and rainfall trend, Mahi ravines.

predominantly from public investment (or lack of it) in infrastructures (irrigation, electricity, roads) and in agricultural research and extension, and from efficient use of water and plant nutrients (Singh, 2002), it is imperative, therefore, to examine the determinants affecting the change in factor productivity.

Determinants of total factor productivity (Pearl millet)

Determinants of total factor productivity (TFP) were examined by regressing the TFP indices of different years with price and non-price factors. These included real price of pearl millet (Rs/ha), rate of interest (%) prevailing, rural road infrastructure in the district (km), rate of inflation (%). Other factors such as, tractors, gross irrigated area etc were omitted from regression as these were observed to be insignificant or absent on these subsistence farms. Extension service was reported by farmers surveyed to be absent in the villages, hence, this was also not considered. A brief description of the policy variable follows,

Table 3. Components of total factor productivity (TFP) in Pearl millet production in Mahi ravines, pooled analysis.

Year	1- c_0w	Average price (Rs/kg)	Index of A	Index of A1	Proportion of TFP explained by incentive effort (%)
1986-1987	0.96	223.80	100.00	100.00	
1987-1988	0.96	206.43	68.84	63.91	92.84
1988-1989	0.94	122.66	124.97	25.72	20.58
1989-1990	0.95	156.54	133.19	45.40	34.09
1990-1991	0.97	210.14	105.38	89.13	84.58
1991-1992	0.97	183.00	93.49	66.10	70.70
1992-1993	0.97	148.32	122.26	41.50	33.95
1993-1994	0.97	171.75	134.47	57.89	43.05
1994-1995	0.98	210.94	93.41	92.04	98.53
1995-1996	0.98	204.27	121.56	86.10	70.84
1996-1997	0.98	186.72	133.69	70.78	52.94
1997-1998	0.98	179.03	161.28	64.57	40.03
1998-1999	0.98	208.11	88.80	80.55	89.94
1999-2000	0.98	206.38	98.85	88.91	89.94
2000-2001	0.99	206.56	68.43	59.15	86.43
2001-2002	0.99	161.69	68.38	52.30	76.48

Real price of pearl millet: This reflects the real purchasing power of a rupee earned from this crop and is indirectly correlated with technical push that it provides to productivity growth. This is hypothesized to have positive correlation with TFP growth.

Rate of interest: This was hypothesized to affect farmers risk taking ability in agricultural production. A lower interest rate would prompt farmer to invest on land including soil and water conservation.

Rural road infrastructure: This is hypothesized to provide connectivity to market and thus would have a positive correlation with TFP growth.

Rate of inflation: This has been observed to have mixed relationship. If rise in prices is contemplated to be permanent, farmers tend to withhold decision to exploit land. On the other hand, if the output price rise is considered to be temporary, farmers exploit land to reap benefit. So, accordingly this has positive and/or negative correlation with TFP growth depending upon time horizon.

As expected, the results of the analysis revealed the coefficients of the independent variables to have the desired sign. Rate of interest (-0.691) and rural road infrastructure (0.721) turned out to be statistically significant; while the former was negatively correlated the latter variable was positively correlated with total factor productivity growth (Table 4). A high interest rate would adversely affect the risk taking behavior of the farmers, thereby adversely affecting the total factor productivity growth. Similarly, higher rural road infrastructure would enhance the productivity growth by connecting to the local market. The village surveyed in Mahi ravine area though had motorable roads but the connectivity of road and their maintenance was poor in remote villages closer to River Mahi Sagar. It can be inferred, therefore, that improving banking facilities with cheap loan to the farmers of this region would improve the productivity of the crop through investment on land and thereby, the profit on farm. The financial inclusion as policy support in this region (Pande et al., 2011) should be supported with easy and cheap loan availability. The road infrastructure in the remote villages could be further strengthened with regular maintenance to improve market connectivity. The villages situated close to ravine and away from the local markets were observed to be in poor shape during survey, warranting immediate attention of the policy makers. The share of incentive effort in TFP in the major crop (Pearl millet) of this region worked out to be substantial (21 to 98%) but this incentive failed to push the factor productivity as farmers could not generate sufficient surplus for investment on farm in general and expenditure on soil conservation in particular on the fields. In fact, the real domestic price of this crop declined during the period under study. The non-price determinants of TFP such as rate of interest and rural road infrastructure turned out to be statistically significant. While easy loan facility by banks with accessibility to smallholder farmers could go a long way, access to local market in the region could also be ensured with good connectivity of road. In fact, the poor road maintenance also turned out to be responsible for poor accessibility to nearest bank. It was revealed during the survey that visit

Table 4. Determinants of total factor productivity (TFP), Pearl millet.

Parameter	Coefficient	t- value
Real price of Pearl millet (Rs./ha)	0.391	1.87
Rate of interest (%)	-0.691*	-2.61
Rural road infrastructure (km)	0.721*	2.30
Rate of inflation (%)	-0.034	-0.37
N =	8	
Adjusted R^2 =	0.99	
F (4,4) =	183.35	
Durbin-Watson D Statistic	3.10	

*****Significant at 10% level of significance.

of bank representative and extension personnel was a far cry as some of the interior villages had not seen them for a long time. An earlier study (Pande et al., 2011) also highlighted farmers' poor credit worthiness in the region which adversely affected their ability to take credit for farm investment. This fact in conjunction with adverse interest rate faced by these smallholder farmers makes strong case of easy loan terms along with financial inclusion of the government.

DISCUSSION

The problem of poor land productivity and adoption of conservation practice on smallholder farms have eluded the attention of policy makers, particularly in the marginal lands of ravines. The total factor productivity growth which encompasses the policy variable required to push the farm productivity further, therefore, need to be addressed. Studies have identified several factors addressing which would help adopt new technologies for enhancing crop productivity such as capital and labour constraint, social network, extension contacts (Abdulai and Huffman, 2014). While the factors affecting factor productivity have been examined at macro scale, the factors providing push to factor productivity at micro scale have drawn little attention of scholars. Identification of region specific factors responsible for pushing productivity growth could greatly eliminate the regional disparities in agricultural growth. This warrants assessing the incentive components in total factor productivity. The small farm holdings, particularly along the Mahi ravines, which hold little scope for land tenure security, are irregular in slope and size and, hence, need immediate investment for enhancing productivity. This evidence contrasts the findings elsewhere (Mugonola et al., 2013). Land ownership and security assures reward to cultivator for efforts in enhancing productivity. However, such scope on marginal lands in Mahi ravines does not exist for the reasons identified. While a favourable credit and infrastructure improvement would give a definite push, an initial government intervention to help improve land through soil and water conservation measure shall go a long way in improving the economic conditions of these farms. This is supported by evidence elsewhere also (Jara-Rojas et al., 2013; de Graaff et al., 2013). At country level, factors like government expenditure on infrastructure (Desai and Namboodir, 1997) have been identified to affect productivity. Similarly, improved rural markets have provided impetus to enhance productivity (Rosegrant and Evenson, 1995); such developments at micro level have not been identified by this study. In fact, rural roads- a proxy to rural market was observed to have affected the total factor productivity in this region. It is therefore strongly contended that these policy options should be strengthened to enhance the factor productivity growth. Hence, the central Gujarat region in general and Mahi ravine area in particular would be benefitted immensely.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Notes

The literature on agricultural production functions is abound to support this (Hayami and Ruttan, 1985; Tang, 1980). The specification is also confirmed on cross-sectional data collected in the study.

APPENDIX I

Outputs and inputs for Pearl millet production, Vadodara district.

Year	Total output (Tonnes)	Land (ha)	Labour (person-days)	Material input (tonnes)	Capital (hp)
1986-1987	17600	18600	5309.70	197.38	3943.01
1987-1988	14000	19800	5861.37	197.98	5314.82
1988-1989	22900	20500	6378.29	200.09	4205.09
1989-1990	24100	19700	6362.00	220.79	3980.68
1990-1991	19700	19300	6388.25	242.67	4423.87
1991-1992	17700	18100	6333.84	240.59	4643.71
1992-1993	22000	16500	5903.67	198.67	3697.17
1993-1994	23900	16400	5861.52	222.09	3144.53
1994-1995	17300	15100	5566.73	231.36	3315.22
1995-1996	22100	17900	6798.27	277.07	4430.10
1996-1997	23700	15600	6107.85	243.43	4298.59
1997-1998	28400	18200	7578.47	365.45	4435.68
1998-1999	16300	12800	5489.45	266.63	2713.42
1999-2000	18100	14300	6293.45	297.88	2578.93
2000-2001	12900	11300	5060.96	184.326	2359.31
2001-2002	12900	11300	5191.48	184.32	2681.61

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Microcalorimetric study of microbial activity changes of acrisol in subtropical China under three different land management

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The microcalorimetric method was applied to analyze the influences of successive reforestations with *Eucalyptus granddis × E. uophylla*, *Pinus massoniana*, and continuous sugarcane production on the soil microbial activities. 500 g of each refined representative sample was collected in rainy and dry seasons from four 100 m^2 homogeneously and perfectly defined acrisol quadrats in subtropical China. Two of them were Eucalyptus plantations with 10 (E10) and 20 (E20) year–old stands. The other two were 10–year–old pine tree plantation (P10) and sugarcane land (SL10) correspondingly contiguous to E10 and E20 and used as references for E10 and E20, respectively. Blocks of E10/P10 were 1500 m away from that of E20/SL10. Microcalorimetric experiments were carried out using 1.2 g soil samples and 0.6 ml of solution containing 5.0 mg of glucose and 5.0 mg of ammonium sulphate at 28°C. The effects of land management practice on soil quality were examined by measuring their physicochemical and biological properties. The results showed that: 1) zymogeneous bacteria were the dominated microbes in the land of continuous sugarcane production, but autochthonous floras were the ones for forest; 2) when compared with its control (SL10), land of eucalyptus (E20) had lower soil packing degree and inhibitory effect on microbial activities, but higher seasonal fluctuation in microbe constitution and activities under the same circumstance; 3) compared with its control P10, the land of eucalyptus E10 had alike soil packing degree and higher seasonal fluctuation degree of microbial activities, but lower inhabiting degree of soil microbial metabolism.

Key words: Microcalorimetry, microbial activity, eucalyptus, pine tree, sugarcane.

INTRODUCTION

As essential components of terrestrial ecosystems, soil microbes play significant roles in decomposing organic materials and nutrient circulation. They are more sensitive to environment stress in their community composition and biomass and dynamic profile than other plants and animals, thus are commonly used as earliest indicators of many ecosystem processes (Dilly and Munch, 1998; Hernot and Robertson, 1994; Nannipieri et

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al., 1990). Living state of soil microbes are easily influenced by the soil conditions such as soil texture, porosity, pH, C–to–N ratio, salinity, especially the content of water and organic matter (Aanderud et al., 2008; Fierer et al., 2003; Rajaniemi and Allison, 2009), but this does not mean that the soil microbes are conformists against soil conditions. In fact, the soil conditions are energetically transformed by the microbes throug changing their community composition, biomass and metabolism (Nsabimana et al., 2004). However, soil properties are chiefly transformed by land management such as tillage mode, planting vegetation species and fertilization (Zheng et al., 2007; Aanderud et al., 2008). Quite a few researchers have intensively investigated the effects of soil microbial activities on the actual soil quality or ecosystem processes with the purpose of optimizing strategy for land exploitation (Banning et al., 2012; Zhang and Chu, 2011).

Ascribe to a burgeoning demand for wood and wood fiber products in domestic as well as international market; a rapid expansion of eucalyptus plantations has taken place in the Southern China in the last 20 years (Wu and Zhang, 2006). Now, Eucalyptus forest has clothed a large area of barren mountains (about 1.7 million ha, 2012) in the Southern China and the local residents income was greatly increased through selling Eucalyptus timber (Wu and Zhang, 2006).

However, just as the other eucalyptus planted regions in the world, eucalyptus reforestation is still a controversial issue in China as consideration of the understory plant diversity, soil fertility and soil biodiversity (Xue, 2009). Based on analyses of phospholipid fatty acids (PLFA) of soil microbial communities and soil primary physico–chemical parameters in Chronosequence Eucalyptus plantations in south China, Cao et al. (2010) found that PLFA as well as the amount of soil TN and SOC (soil organic carbon) were higher in 13–year–old–Eucalyptus plantations than those in younger ones, and suggested that the soil properties and the community structure of soil microbes were not negatively affected by reforestation of Eucalyptus. But this did not mean that eucalyptus exerting nothing negative on the soil microbial community composition (Cao et al., 2010).

Inconsistently, some research results have shown that Eucalyptus reforestation less ameliorated or even degraded the soil quality in aspect of soil porosity, bulk density, total organic carbon/nitrogen, microbial biomass and microbial metabolic quotient or some essential enzyme activities (Jeddi et al., 2009; Lisardo Nu´n˜ez–Regueira et al., 2006; Behera and Sahani, 2003; Sicardi et al., 2004). It is obvious that discrepancy exists in accounting for relationship of soil quality and Eucalyptus reforestation. Soil quality status was principally characterized by the SOC (soil organic matter content), field water capacity, air–filled porosity, pH and soil bulk density of the top soil, and TN, mean diameter of cumularspharolith (Shukla et al., 2006), but also characterized by the microbial biomass, microbial community composition, soil respiration and enzyme activity (Yakovchenko et al., 1996; Filip et al., 2002). There are agreements on the physical–chemical and biological properties as the soil quality indicators (Klein et al., 1985), but inconsistent opinions also exist as to the biochemical ones, especially the enzyme activity (Trasar–Cepeda, 2008; Sicardi et al., 2004). A large group of soil tests have indicated that the decrease or increase in enzyme activity did not always occur in all enzymes of microbes for a special type of land use, and the absolute values of different enzyme activities did not always show explicit relationship against the reduction or increase in the organic matter content resulted from soil use (Trasar–Cepeda et al., 2008). In fact, effects of decrease of organic matter content on the enzyme activity depend on the type of land use and the type of enzyme (Trasar–Cepeda et al., 2008).

Microcalorimetric method have been applied to study soil and environmental sciences and confirmed to be a valid alternative method in study of soil microbial biomass, metabolism and growth state (Roxg et al., 2007; Lisardo Nu´n˜ez–Regueira et al., 2006; Sigstad et al., 2002). With this alternative method and measurement of physical and chemical properties, Nhiiez–Regueira et al. (2005) successfully established an experimental procedure to assess the productivity and health of soil under two types of land managements. Meanwhile, they also quantified the effect of land use on the soil quality (Nuiiez–Regueira et al., 2005).

The outstanding advantages of the microcalorimetric method are: 1) continuously *in situ* monitoring the activity of life process for a long–term without disturbing the system; 2) independent of the type of microorganisms and their form of evolution because the method only records the initial and final energy state of the system; and 3) highly sensitive and very simple (Ljungholm et al., 1979a; Zheng et al., 2009). With the expansion of Eucalyptus reforestation in southern China, attention have focused on the plant community composition, soil properties, Eucalyptus growth state and efficient of water utilization in the Eucalyptus forest (Chen et al., 2006; Lu et al., 2005; Cao et al., 2010). But so far, no study was conducted on the activity of soil microbes in the Eucalyptus plantations using microcalorimctric method in China.

As the microcalorimetric technique has corroborated validity of studying microbial activity in soils (Wu et al., 1996; Critter et al., 2002; Zheng et al., 2007), the present study are aimed to analyze the effects of three types of land management practice (consecutive plantation of Eucalyptus, pine, sugarcane) on the microbial activity in soils, to investigate the relationship between dynamic of soil microbe and the specific soil properties that is, soil moisture, soil pH, soil organic carbon content, and to assess which management practice mentioned earlier is more favorable to maintaining soil health and high productive potential in the local climate.

MATERIALS AND METHODS

Study area and sampling

The experimental sites are located in Dongmen town (22°51' to 22°55' N and 113°44' to 113°53' E), Fusui county, Guangxi Zhuang Autonomous Region, southern China. This area is a region with topographic features of karst–localized low hilly tablelands. Half of its total tillable soil is used for reforestation of eucalyptus and pine trees (98% of which is for eucalyptus) and the other half is for vegetation of sugarcane. It has a subtropical monsoon climate with an average annual temperature of 20 ~ 25°C, and the highest and lowest average monthly temperatures of 28.2°C (July) and 13.4°C (January). The average annual rainfall is 1000 ~ 1200 mm with 80% of it falling in April to September. So the climate is clearly divided into rainy season (April to September) and dry one (October to March). The soil is Acrisol developed from granite. Textures of the surface soils vary from sandy loams to clay loams while subsoils are clays to heavy clays (Xiang et al., 2006). The sampling plots for this study were Eucalyptus (*Eucalyptus granddis* × *E. uophylla*) plantations of two stand–growth–ages, the 20–year–old (E20) (reforestation 20 years ago for demonstration) and 10–year–old (E10) (reforestation for timber production 10 years ago, the present stands are result of sprout regeneration, the first generation was fallen 5 years ago), pine (*Pinus massoniana*) plantation with stands of 10 years (P10) and sugarcane land (SL10).

The sugarcane land plantation has been subjected to the local conventional tillage type for more than 10 years, namely that sugarcanes are harvested during December and February and the residues were left to cover the surface soil until the March to April when soil–incorporation and first fertilization was conducted using moldboard-plow. The second fertilization was conducted in June to July. The intensity of fertilization usually was about 750 kg/ha and the sugarcane stubbles were replaced every three years. All the works were done in farming way. Compound fertilizer with the content of N being about 10.0, P_2O_5 about 7.4 and K_2O about 12.0 g per 100 kg was usually applied. The mean yield of sugarcane generally was 90 to 120 tons/ha. Planting density was 625 stands/ha for E10 and P10 and 400 stands/ha for E20. Management practice for the Eucalyptus and pine plantations usually was weeds–bush–hoed for reforestation in the period of March to May followed by weed control with hand work and fertilization of the tree–lets with a model of pot–like–hole digging in the first three years. The forest land was fertilized with Eucalyptus–special fertilizer at half intensity for the sugarcane land. The mean yield of merchantable timber under such a practices generally was 90 to 120 m^3/ha for Eucalyptus in each rotation period (average 6 years). Pine plantations were initially reforested as control for scientific research on the Eucalyptus timber production and have not fallen yet till now. The understory of P10 forest is a tall shrub layer dominated by *litsea glutinosa* and *Evodia lepta*, a shrub layer dominated by *Rhodomyrtus tomentosa*, *Miscanthus sinensis*, *Ficus simplicissima* Lour. [F. hirta Vahl var. *Palmatilob*a (Merr.) Chun], *Ligustrum quihoui Carr*, *Trema angustifolia* (Planch.), *Lygodium japonicum* (Thunb.) Sw. species and a ground layer of *Dicranopteris linearis*, *Arthraxon lanceolatus* (Roxb.) Hochst.

The understory of the E10 forest is a tall shrub layer comprised of *l. glutinosa*, *E. lepta*, *Mallotus paniculatus* and *Rhus chinensis*, *a* shrub layer dominated by *T. angustifolia* (Planch.), *Ficus simplicissima* Lour. [F. hirta Vahl var. *Palmatilob*a (Merr.) Chun] and *L. quihoui Carr*. and a ground layer dominated by *D. linearis* and *A. lanceolatus* (Roxb.) Hochst. However, no figuration understory was found in the E20 forest except the sporadic distribution of *D. linearis*. The average height of trees is about 20, 30 and 18 m in E10, E20 and P10 forest, respectively. The slope gradient of all the study plots is no more than 5%, and the canopy density of the E10, E20 and P10 is about 70, 90 and 70%, respectively. The E10 was contiguous to P10 and E20 was contiguous to SL10. E10 had opposite slope orientation to P10, E20 had opposite slope orientation to SL10. Block of E10/P10 was 1500 m away from that of E20/SL10. Such a distribution pattern of vegetation offers a rare opportunity to compare how reforestation of Eucalyptus affects soil microbial community composition and their activity against reforestation of native tree species of *P. massoniana* and sugarcane cropping in the texture–alike soil under the same climatic condition. For sample collection, 100 m^2 of land was delimited as the plot and divided into 1 m^2 ones. Five noncontiguous plots were randomly chosen. After removal of the fallen foliage and litter, 1 kg of soil was taken at the depth of 5 to 20 cm and processed through coning and quartering procedure (Petersen et al., 1995). A total of 500 g of each highly homogenized soil samples was placed in a polyethylene bag tabbed with requisite information (date and time of sampling, orientation of slope, topography of the zone, characteristics of understory vegetation, soil colour, etc) to avoid contamination and loss of moisture. These bags were sent back to the laboratory in less than 10 h and stored at 4°C to keep field conditions as steady as possible until indoor work started in no more than 24 h. Sampling was conducted twice a year at rainy season (26-05-2012) and dry season (26-12-2012). Each sample was divided into two fractions, one fraction (E10-1, P10-1, E20-1 and SL10-1) was used for microcalorimetric experiments and the other fraction (E10-2, P10-2, E20-2, and SL10-2) was used for measurement of physical, chemical and biological properties.

Soil analysis

Determination of the physical properties

Soil moisture was determined by incubating samples in an oven at 105°C to a constant weight. Soil pH was measured through soil water suspension (1:2.5 v:v) with a digital pH meter (Thomas, 1996). Bulk density was determined by the cylinder method. In brief, soil samples were carefully introduced into a 6.5 cm diameter and 7.5 cm high cylinder to avoid generating compaction. After being sent to the laboratory, the cylinder was placed in an oven and incubated at 105 to 110°C to constant weight. Bulk density was then calculated from the dry weight and occupied volume values of the sample. Values of moisture and actual density of sample were calculated at the same time. Total porosity, aeration porosity and water porosity were determined as previously reported (Liu et al., 1996). Values of physical properties are shown as the mean of that of samples colleting in rainy and dry season.

Determination of the chemical properties

Soil organic materials (OM) were valuated using dichromate oxidation method and total N (TN) was determined using an ultraviolet spectrophotometer after Kjeldahl digestion (Liu et al., 1996). Soil total P was determined by molybdenum–blue colorimetry after digested with HF–$HClO_4$ (Jackson, 1958). Values of chemical properties are shown as the mean of that of samples colleting in rainy and dry season.

Determination of biological properties

The number of living microorganisms was estimated by viable count on serial spread plates as reported previously (Zheng et., 2007). In a nutshell, 10 g of each soil sample was suspended in 90 ml of sterilized phosphate buffered saline and continuously diluted by 10–fold for 6 times. Then, 0.1 ml of the diluted sample suspension was spread over an agar plate with Martin's medium for fungi, a plate with beef extract peptone medium for bacteria and a plate with Gause's No. 1 synthetic medium for actinomycetes. The plates were incubated at 28°C until colonies appeared (2 days for bacteria and 5 days for fungi and actinomycetes). The experiment was performed in triplicates and colony forming units (CFU) were counted independently for three times.

Microcalorimetric measurements

The microcalorimetric test was conducted on a 3114/3236 thermal active monitor (TAM^{TM}) air eight–channel isothermal calorimeter manufactured by Thermometric AB, Stochholm, Sweden. The structure and work principle of this instrument was detailed in other literatures (Ren et al., 2012) or web site of the manufacturer. The measurement was conducted as previously reported (Zheng et al., 2007). In brief, the 5 ml glass ampoules were cleaned and sterilized in an oven at 100°C before use. All soil samples were preheated at 28°C for one day and then measured microcalorimetrically. 1.2 g of soil sample was placed in a sterilized glass ampoule and then 0.6 ml of a solution containing 5.0 mg of glucose and 5.0 mg of ammonium sulphate was added. To control evaporation and energy loss, the ampoules were hermetically closed using Teflon sealing discs. The temperature of the calorimeter system and the isothermal box was controlled at 28°C. The heat flow rate of microbial growth was continuously monitored with a thermal activity monitor and recorded with a computer to plot time–power curve. Three repeats of measurement for each sample were done and only one power–time curve from these measurements was analyzed since high repeatability was seen with the three parallel records (Zheng et al., 2007).

The thermodynamic parameters including growth rate constant (k), the maximum thermal power (P_{max}), the time of reaching the maximum peak (t_{max}) and total heat dissipation (Q_t) were obtained directly or by integrating the power–time curves. Among them, the k obeys the following thermokinetic equation (Yao et al., 2008):

$$\ln P_t = \ln P_0 + kt$$

Where t is time, P_t is the power output at time t, P_0 is the power at time t = 0 and k is the growth rate constant calculated from the slope of semi–logarithm of the exponential phases. The Q_t is the sum of thermal power during organic material consumption and reflects the activities of soil microbes (Yao et al., 2008).

Statistical analyses

The results of microbial numbers and that of soil physical and chemical properties were given as the arithmetic mean of three independent measurements. Pearson correlation analysis was performed with SPSS 11.5 software (SPSS Inc., 2002).

RESULTS

Soil physical and chemical property

Table 1 lists the main physical and chemical properties of soil samples. It is obvious that: 1) E20/SL10 plots had higher organic matter content than E10/P10 plots; 2) E10 plot had the lowest total nitrogen content, while the other three plots had similar total nitrogen content; 3) P10 plot had the lowest total phosphorus content; 4) C/N ratio of the four plots was out of the range of 10 to 15, which was not sustainable for microbe growth in soils. Plots P10, E20 and SL10 were more favorable to microbe growth because they had more abundant nitrogen. All forest soil samples were acidic except the sugarcane one was neutral. The two Eucalyptus plantations E10 and E20 were more acidic than their control P10 and SL10 accordingly. No significant difference was observed in soil actual density among the four plots although the SL10 had the highest bulk density. Among the four samples, E20 had the lowest water porosity, while SL10 had the lowest air porosity.

Microbial numbers and their relationship with type of land use and season alternation

Table 1 shows the mean values of microbial numbers for all soil samples. It is demonstrated that varies in type of land use and season alternation greatly affected soil microbial numbers and their composition. In both rainy and dry seasons, SL10 collected from sugarcane land was influenced most by human activities, showing the highest bacterium number. By contrary, soil samples of E20, E10 and P10 collected from regeneration forest were lest influenced by human activities, containing lower bacterium numbers. Fluctuation in number of soil microbes with seasonal change was particularly notable for the samples collected from forest land, which wasmuch higher in E10 and E20 from Eucalyptus plantation than that in their control P10 and SL10, respectively. These data indicated that number and constitution of microorganisms in Eucalyptus plantation were more unstable than the one originated from sugarcane or the indigenous varieties of pine tree.

Microbial activity measured by microcalorimetric method

Table 2, Figures 1 and 2 display the results of calorimetric tests for all soil samples collected in rainy and dry seasons. Traces of microbial activity from different biotope were recorded as distinguishable power–time curves. They all presented a typical process of microbial metabolic activity. Just as the typical growth curve of microbes, after a lag phase, the heat flow increased exponentially which was followed by a stationary phase and a decline phase. Comparison of the power–time curves of the four samples collected in rainy season with those in dry season showed that samples collected in rainy season had second peaks and the segments in the curves containing the second peak were nearly parallel, which were not seen in samples collected in dry season. According to Yao et al., (2008), the second peaks may be caused by: 1) the growth of different microbial communities; 2) same microorganisms utilize

Table 1. Physicochemical, and biological properties corresponding to soils from E10, E20, P10 and SL10.

Variable	E10	E20	P10	SL10
Residual moisture (%)	3.4±0.283	4.65±0.354	3.4±0.283	6.25±0.071
Bulk density (g cm^{-3})	1.08±0.028	1.19±0.014	1.09±0.085	1.23±0.007
Actual Density (g cm^{-3})	2.85±0.502	2.33±0.056	3.01±0.834	2.37±0.113
Total porosity (%)	55.15±0.919	47.85±3.323	53.6±2.121	48.25±2.758
Air porosity (%)	17.35	16.66	18.78	13.28
Water porosity (%)	37.8	31.19	34.82	34.97
Field capacity (%)	47.65±1.450	53.65±0.636	48.95±0.212	50.65±0.778
pH	6.0±0.154	6.3±0.103	6.4±0.142	7.0±0.135
C–to–N ratio	15.988	17.505	16.079	18.236
Organic matter content (g.kg^{-1})	38.637±0.718	48.886±0.436	41.912±1.095	48.716±0.691
Total nitrogen content (g.kg^{-1})	2.417±0.083	2.793±0.069	2.607±0.051	2.672±0.116
Total phosphorus content (g.kg^{-1})	0.496±0.008	0.580±0.031	0.3841±0.028	0.686±0.023

Soil microorganisms (CFU.g^{-1})	Rainy season				Dry season			
	E10	E20	P10	SL10	E10	E20	P10	SL10
Bacteria (×10^5)	6.452±0.65	24.57±0.16	1.524±0.09	2687±0.37	0.1084±0.145	6.8124±0.0652	1.318±0.0974	2356±0.247
Actinomycetes (×10^4)	0.636±0.48	26.75±0.132	27.37±0.134	2.698±0.15	8.574±0.62	158.7±0.132	66.812±0.213	1.273±0.128
Fungi (×10^4)	3.694±0.23	433.2±0.21	21.39±0.14	2.318±0.18	4.283±0.351	614.1±0.312	52.431±0.281	4.691±0.201
Total (×10^5)	6.975	70.475.	6.13	2687.502	0.1394	84.002	13.242	2356.596

different carbon sources besides glucose added at the beginning of the experiment; and 3) adaptation of soil anaerobes to anaerobic conditions. In our experiment, the volume of the measuring cell in the glass ampoule was 5.0 ml, and 3.0 ml air was left after adding the soil sample and the aqua. At the beginning of the test, oxygen in the room above the soil sample in the airtight glass ampoule was available for soil microbes, which was initially in favor of aerobes. When the oxygen was consumed, the condition was more favorable to anaerobes. This may explain why there were two typical peaks. It was worth the whistle that segments in the curves containing the second peak were nearly parallel as mentioned earlier; this may be interpreted as that alike microbial communities in these four soil samples were undergoing metabolism using the alike substrates of similar content.

Considering that the nutritional elements in a soil would not completely vanish in a short time of six months, it was most likely that the second peak disappeared in the thermal activity curves of the samples collected in dry season was caused by lacking the corresponding anaerobic microbial communities in samples collected in the rainy season. Contrasting the power–time curves of samples collected in rainy and dry seasons from the same plot, the amplitude of variation (AV) for a specific parameter was obtained by the following equation:

$$Avx = \frac{Rx - Dx}{Rx} \times 100$$

Where AVx was the amplitude of variation for a specific parameter x; Rx and Dx were the amplitude of variation for a specific parameter (x) of samples collected in the rainy season and dry season, respectively.

AV of K (AVk) was 6.41% higher in E10 than that of its control P10, and was 6.84% higher in E20 than that of its control SL10. AV of P_{max}

Table 2. Results from power–time curve measured by microcalorimetric method.

Variable	Rainy season	Dry season	Amplitude of variation (AVx) (%)
E10			
$K(h^{-1})$	0.098262759	0.066569	32.25
P_{max} (μW)	195.2845974	122.477032	37.28
Q_t ($J\ g^{-1}$)	12.0867	9.95916	17.6
T_{max} (h)	25.42339009	48.53522	-90.91
Lnp–t	$P_t = 0.0837t + 2.9528$	$P_t = 0.0998t + 2.3543$	
R	0.9931	0.9695	
E20			
K (h^{-1})	0.189478	0.1169044	38.30
P_{max} (μW)	365.3410146	123.0703586	66.313
Q_t ($J\ g^{-1}$)	13.94005	10.075	27.73
T_{max} (h)	20.37574471	27.10417666	-33.02
Lnp–t	$P_t = 02112t + 1.6464$	$P_t = 0.115t + 2.0216$	
R	0.9986	0.9746	
P10			
K (h^{-1})	0.1672	0.12399309269	25.84
P_{max} (μW)	172.17807645	153.5861077	10.798
Q_t ($J\ g^{-1}$)	9.71152	9.143625	5.85
T_{max} (h)	28.78647841	47.5587	-65.21
Lnp–t	$P_t = 0.0641t + 3.0309$	$P_t = 0.1197t + 2.1497$	
R	0.9863	0.9931	
SL10			
K (h^{-1})	0.2091915	0.143133	31.58
P_{max} (μW)	364.18897	336.7499691	7.5
Q_t ($J\ g^{-1}$)	12.41447	10.04017	19.1075
T_{max} (h)	18.007.	23.15078	-28.57
Lnp–t	$P_t = 0.1886t - 22.3559$	$P_t = 0.462t + 2.2953$	
R	0.9929	0.9961	

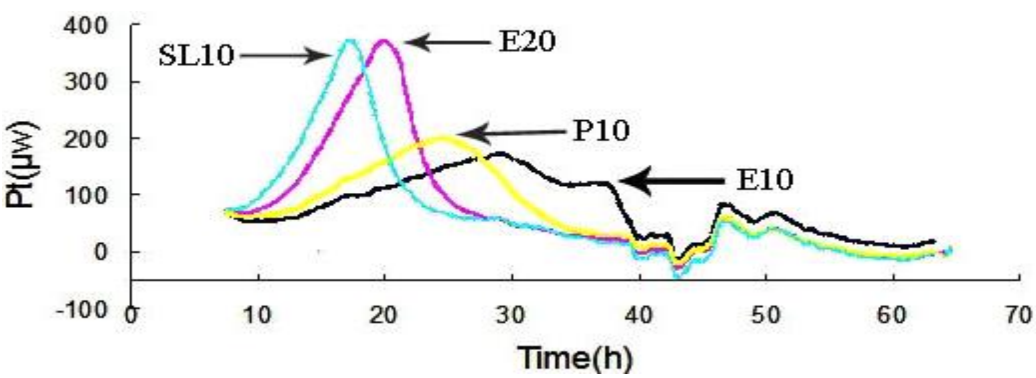

Figure 1. Power–time curves recorded microcalorimetrically by supplementing glucose and ammonium sulphate into the four soil samples collected in rainy season. In these curves, thermal power (μw) is plotted against time (h). Integration of these curves provides values of the total heat evolved in the process. The evolution of peak height (P_{max}) is the power at the maximum of the peak, and peak time (T_{max}) is the time to reach the maximum of the peak.

(AVP_{max}) and Q_t (AVQ_t) were 26.482 and 11.75% higher in E10 than those of its control P10, respectively, and 58.813 and 8.623% higher in E20 than those of its control SL10, respectively. AV of T_{max} (AVT_{max}) was 25.3% higher in E10 than that of its control P10, and 4.45% higher in E20 than that of its control SL10. These data

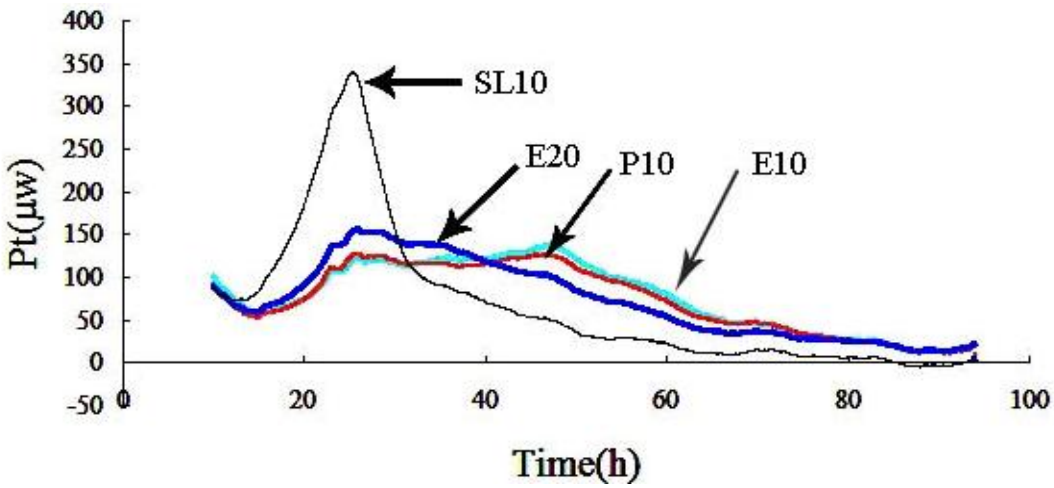

Figure 2. Power–time curves recorded microcalorimetrically by supplementing glucose and ammonium sulphate into the four soil samples collected in dry season. In these curves, thermal power (µw) is plotted against time (h). Integration of these curves provides values of the total heat evolved in the process. The evolution of peak height (P_{max}) is the power at the maximum of the peak, and peak time (T_{max}) is the time to reach the maximum of the peak.

indicated that season alternation had higher influence on microbe activities in soil of Eucalyptus plantation than in soil used for vegetation of sugarcane and pine under the local climate condition. This was in consistence with the ratiocination in the soil analysis. Both the power–time curves of samples collected in rainy and dry seasons can be divided into two groups based on microbial growth process. Samples collected in rainy season from SL10 and E20, which were the land of sugarcane and 20–year–old Eucalyptus stand and contiguous to each other, lacked a lag phase and showed rapid microbial growth at the beginning (Figure 1), while samples collected in rainy season from E10 and P10, which were the land of 10–yesar–old Eucalyptus and 10–year–old pine tree and contiguous to each other, presented a longer lag phase (Figure 1). Differently, only samples collected in the dry season from SL10 showed rapid microbial growth at the beginning, and all the other samples collected from E20, E10 and P10 showed longer lag phase (Figure 2). Obviously, power–time curves were consistent with their bacterial numbers (Table 1). Taken together, the bacterial quantity data and microbial activity curves indicated that zymogenous bacteria were the main community for soil sample SL10 in both rainy and dry seasons and for soil sample E20 in the rainy season, while the autochthonous floras were the dominant microbial communities in soil sample E20 in the dry season and in soil samples E10 and P10 in both rainy and dry seasons.

For parameters of all the power–time curves, K (the microbial growth rate constant during the log phase or the exponential phase of microbial activity curves), T_{max} (h) (the time to reach the peak) and P_{max} (µw) (the peak of heat evolution) also presented the same trend as mentioned earlier (Figures 1, 2 and Table 2).

The K value was positively correlated with bacterial number with Pearson's correlation coefficient value of 0.681 and 0.842 for samples collected in the rainy and dry seasons, respectively (Figure 3). T_{max} was negatively correlated with bacterial number with Pearson's correlation coefficient of -0.902 and -0.683 for samples collected in rainy and dry seasons, respectively (Figure 4). P_{max} was positively correlated with bacterial number with Pearson's correlation coefficient of 0.793 and 0.914 for samples collected in rainy and dry seasons, respectively.

The heat evolution of samples E10 and P10 had longer stationary phase (Figures 1, 2, 5 and 6). By contrast, the Q_t (the value of total heat released by soil microorganisms) had weak correlation with the total number of culturable soil microorganisms, showing Pearson's correlation coefficient of 0.465 and 0.329 for samples collected in the rainy and dry seasons, respectively (Figures 7 and 8).

DISCUSSION

Relationship between land use type and soil physical/chemical properties

Actual density ($kg.m^{-3}$) of all the samples from land under three management types was not significantly different, indicating that all the tested lands were developed from the same mother rock. Sample from SL10 had the highest bulk density ($kg.m^{-3}$), but the lower total porosity among the samples, suggesting that the packing degree of soil from SL10 was higher than those of the other three samples. The higher packing degree of soil from SL10

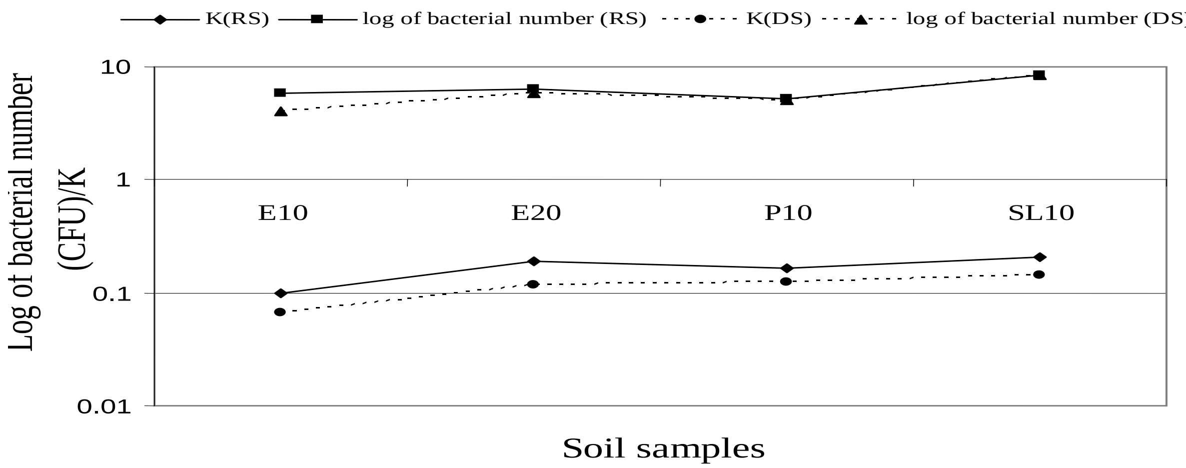

Figure 3. Growth rate constant (k) and log colony forming units of bacteria of soil samples collected both in rainy and dry season. The value of k increased with bacterial quantity increasing and positively correlated with bacterial quantity with Pearson's correlation coefficient of 0.681 and 0.842 for rainy and dry seasons, respectively.

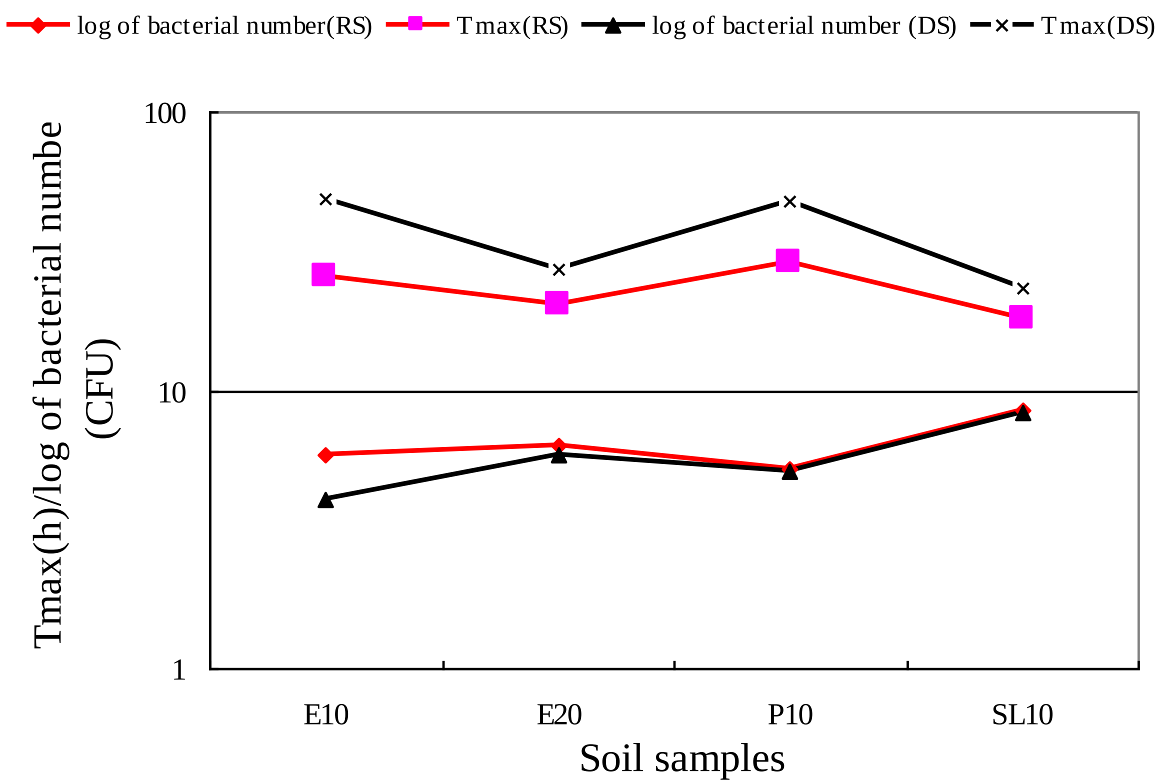

Figure 4. The peak time (the time to reach the peak, T_{max}) inversely related to the log colony forming units of bacteria of samples collected in rainy season (RS) (Pearson's correlation coefficient of -0.902) and dry season (DS) (Pearson's correlation coefficient of -0.683). T_{max} presented as two groups, the group of E10 and P10 showed higher T_{max} value but lower bacterial numbers than the group of E20 and SL10.

may be correlated with frequent human activities such as harvest, fertilization, but most of all, long–term, intense use of chemical fertilizers. However, the packing degree of soil from SL10 was not high enough to restrict microbial activities, it only influences soil aeration by directly affecting total porosity. In some cases, due to the

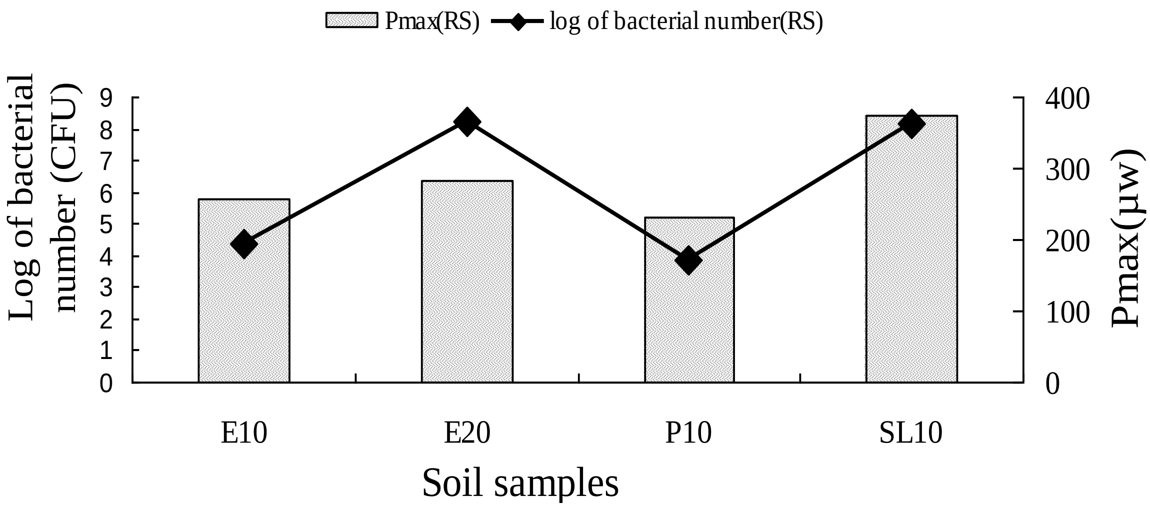

Figure 5. Positive correlation with Pearson's correlation coefficient of 0.793 was found between the maximum thermal power (P_{max}) and the log of bacterial number of samples collected in rainy season.

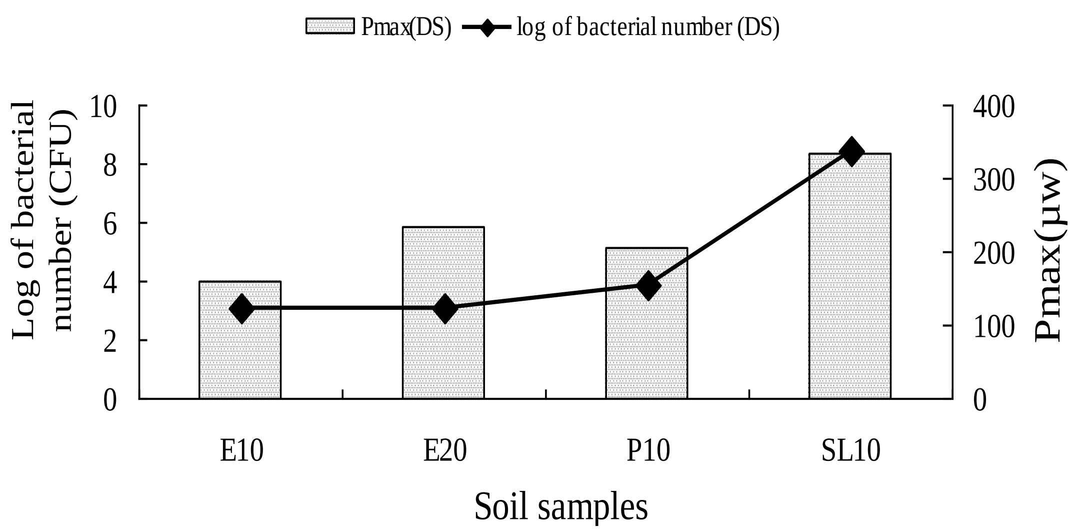

Figure 6. Positive correlation with Pearson's correlation coefficient of 0.914 was found between the maximum thermal power (P_{max}) and the log of bacterial number of samples collected in dry season.

formation of surface and subsurface compact layers, its resulted drainage restriction, flooding and anoxia can adversely affect microbial growth and activities (Lisardo Nu´n˜ez–Regueira et al., 2006). Higher total porosity and lower bulk density for samples from E10 and P10 usually originate faster water vertical motion and subsequently result in lower field capacity (Table 1). However, because organic matters could absorb enough water to maintain a significant biological activity, this dose not adversely affect soil microbial growth and activities (Lisardo Nu´n˜ez–Regueira et al., 2006).

The results that soil from E10 and P10 had almost the same total, air, water porosity and field capacity indicated that the packing degree of them was alike.

The total porosity of soil from E20 and SL10 is not significant different, however the former has higher air but lower water porosity than its control SL10, these suggest that the packing degree of sugarcane land is higher than that of the E20 land.

Relationship between organic matter (OM) and microbial quantity and activity

It was generally believed that OM is positively correlated with the number, biomass and activity of microbes in soil

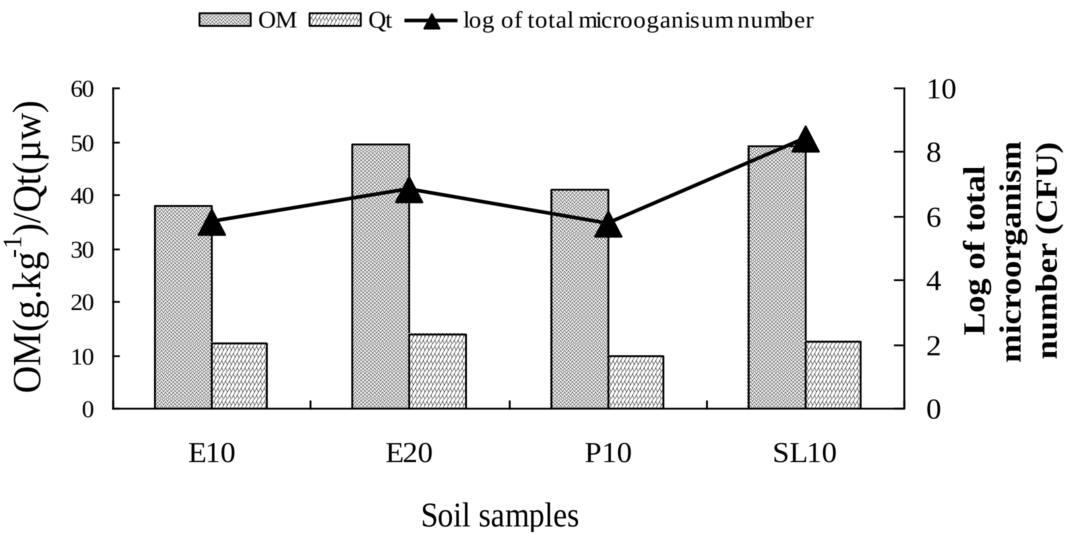

Figure 7. Positive relationship among organic matter (OM), log of total colony forming units and the value of total heat released by soil microorganisms (Q_t) for samples collected in rainy season. The Pearson's correlation coefficient was 0.821 between the OM and log of total colony forming units, 0.620 between OM and Q_t, and 0.465 between Q_t and log of total colony forming units, respectively.

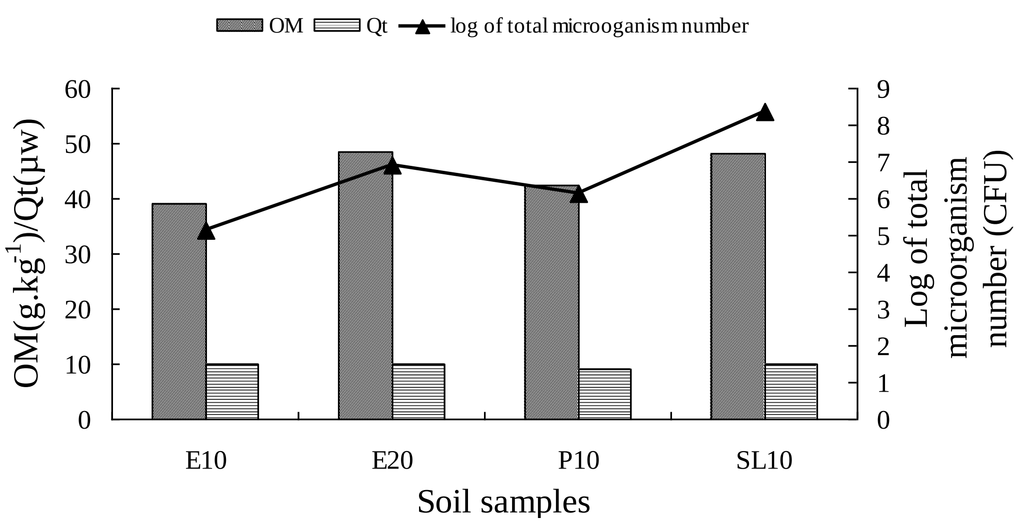

Figure 8. Positive relationship among organic matter (OM), log of total colony forming units and the value of total heat released by soil microorganisms (Q_t) for samples collected in dry season. The Pearson's correlation coefficient was 0.887 between OM and log of total colony forming units, 0.409 between OM and Q_t, and 0.329 between Q_t and log of total colony forming units, respectively.

(Barros et al., 1997). In agreement with that, our results also indicated that OM is positively correlated with the total number of culturable microbes, with Pearson correlation coefficient as high as 0.821 and 0.887 for samples collected in rainy and dry season, respectively (Figures 7 and 8). Although, Q_t is positively correlated with OM and the total number of culturable microbes, their Pearson's correlation coefficient is relatively low (Figures 7 and 8), suggesting that metabolism of soil microbial communities is inhibited by some ill–defined elements while experiments were conducted, even in the original circumstances. Meanwhile, the heat flow generated by per CFU was much higher for samples from E10 and E20 than that of their control samples from P10 and SL10, regardless of rainy or dry seasons (Figures 9 and 10). Taking together, the results indicate that inhibiting degree of microbe's metabolism for soil samples from P10 and SL10 was much stronger than that from E10 and E20. Unfortunately, we were unable to determine whether this differentiation is caused by

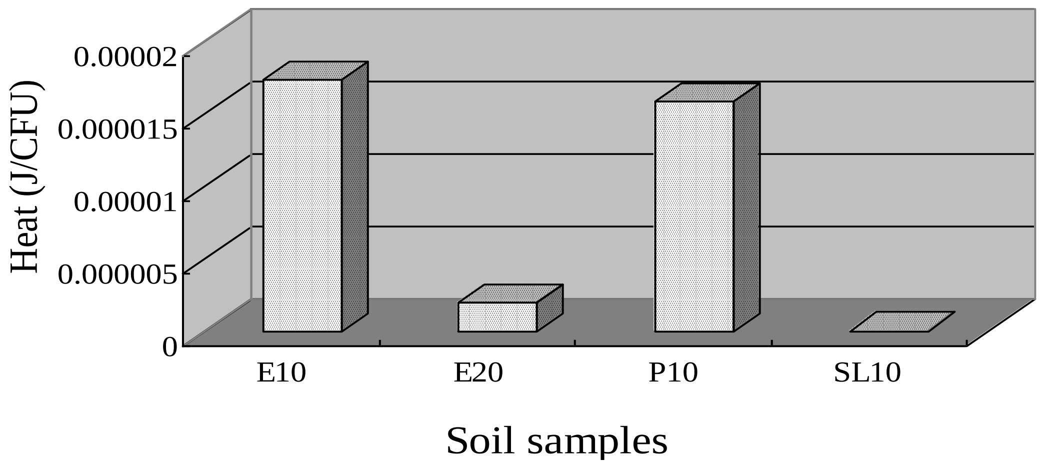

Figure 9. The heat flow generated by per CFU (J/CFU) of samples collected in rainy season.

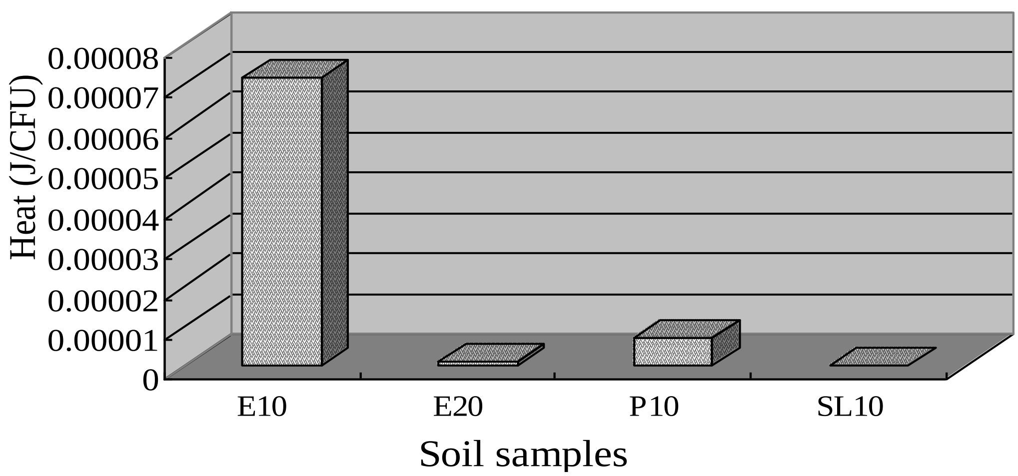

Figure 10. The heat flow generated by per CFU (J/CFU) of samples collected in dry season.

different dose effect of same inhibitors or by totally different inhibitors.

Conclusions

In this study, we analyzed the effects of three types of land management practice (consecutive plantation of Eucalyptus, pine, sugarcane) on soil microbial activity, investigated the relationship between soil microbial activities measured by using microcalorimetric method and specific soil properties (soil moisture, soil pH, soil organic carbon content) and assessed the effect of management practice on maintaining soil health and high productive potential. Taking together, we concluded as follows:

1) Zymogenous bacteria were the dominant microbes in the land of continuous sugarcane production but autochthonous floras were the one in the land of forest.
2) Compared with its control (land of continuous sugarcane, SL10), the land of eucalyptus E20 had lower soil packing degree and inhibition against soil microbe activities, but higher seasonal fluctuation degree of soil microbial activities and constitution under the same circumstance.
3) Compared with its control P10, the land of eucalyptus E10 had similar soil packing degree and higher seasonal fluctuation degree of microbial activities, but lower inhabiting degree of soil microbial metabolism.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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